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The MEND Board of Directors
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MEND/NEDEM

MINE ENVIRONMENT NEUTRAL DRAINAGE PROGRAM

PROGRAMME DE LA NEUTRALISATION DES EAUX DE DRAINAGE DANS L'ENVIRONNEMENT MINIER

Mr. J. White
Chairman, MEND Board of Directors
Noranda Inc.
Suite 2700, 1 Adelaide St. E.
Toronto, Ontario
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Dear Mr. White:

On behalf of the Management and Technical committees of MEND, I am pleased to submit to you the MEND Annual Report for 1992.

Copies have been sent to other Board members for their review before the Board meeting of March 9, 1993.

Yours truly,

I.J. Itzkovitch
Chairman
MEND Management committee

MEND PARTICIPANTS NEDEM

Atomic Energy Control Board
Canada Centre for Mineral and Energy Technology
Energy Mines and Resources Canada
Environment Canada
Indian and Northern Affairs Canada
BP Resources Limited, Mining Division
Brunswick Mining & Smelting
Cambior Inc.
Cape Breton Development Corporation
Cominco Limited
Curragh Resources Limited
Denison Mines Limited
Echo Bay Mines Limited
Falconbridge Limited
Homestake Canada
Hudson Bay Mining and Smelting Company Limited
INCO Limited
Lac Minerals
Les Mines Selbaie
Mining Industry Technology Council of Canada
Noranda Minerals Inc.
Placer Dome Inc.
Rio Algom Limited
Teck Corporation
Westmin Resources Limited
The Mining Association of Canada
The Mining Association of British Columbia
The Mining Association of Ontario
British Columbia Ministry of Energy, Mines and
Petroleum Resources
Manitoba Energy and Mines
New Brunswick Department of Natural Resources and Energy
Ontario Ministry of Northern Development and Mines
Ontario Ministry of Environment
Ministère de l'Énergie et des Ressources du Québec
Centre de recherches minérales
Ministère de l'Environnement du Québec
Saskatchewan Environment

Associate Participants Associés

Australian Nuclear Science and Technology Organization
Norwegian Pollution Control Authority
Swedish National Environmental Protection Board
United States Bureau of Mines
University of British Columbia
University of West Virginia
University of Waterloo
Laurentian University
United States Environmental Protection Agency

March 1993

MEND (**M**ine **E**nvironment **N**eutral **D**rainage) is a co-operative research program sponsored, financed and administered by 3 partners; the Canadian mining industry, the Government of Canada and the Governments of the provinces of British Columbia, Manitoba, Ontario, Québec and New Brunswick. The objectives of MEND are to:

- provide a comprehensive, scientific, technical and economic basis for the mining industry and government agencies, to predict with confidence the long term management requirements for reactive tailings and waste rock; and

- establish techniques that will enable the operation and closure of acid-generating tailings and waste rock disposal areas in a **predictable, timely, affordable,** and **environmentally acceptable** manner.

Six committees direct and manage the technical components of the program: Prediction; Prevention & Control; Treatment; Monitoring; Technology Transfer; and International Liaison. These committees have specific mandates to develop techniques that reduce the environmental impact and financial liabilities caused by acidic drainage. A Management committee is responsible for managing the overall program and a Board of Directors reviews and approves budgets and program direction. The MEND Secretariat coordinates the activities of the committees and their respective programs.

The MEND program of research was redefined and refocussed in 1992, and this program is outlined in the **Revised Research Plan, 1992**. Included in this Plan, is a component on New Ideas and Innovation, which was established to solicit, assess, and fund new ideas that will lead to breakthrough technologies in the prevention and control of acid mine drainage.

NEDEM (**N**eutralisation des **E**aux de **D**rainage dans l'**E**nvironnement **M**inier) est un programme de recherche qui est parrainé, financé et administré conjointement par 3 partenaires; l'industrie minière canadienne, le gouvernement fédéral et les gouvernements de la Colombie-Britannique, du Manitoba, de l'Ontario, du Québec et du Nouveau-Brunswick. Les objectifs de NEDEM sont les suivants:

- établir les fondements scientifiques, techniques et économiques permettant à l'industrie minière et aux organismes gouvernementaux de prédire avec confiance les besoins à long terme en matière de gestion des résidus réactifs et des stériles, et

- mettre au point des techniques permettant l'exploitation et l'abandon, de manière **prévisible, économique opportune et acceptable pour l'environnement**, des aires d'élimination de résidus miniers acides et des stériles.

Le programme est composé de 6 comités techniques: Prévision, Prévention et contrôle, Traitement, Surveillance, Transfert de la technologie et Liaison internationale. Ces comités ont des mandats spécifiques afin d'explorer les différentes voies permettant de réduire l'impact environnemental du drainage acide ainsi que l'engagement financier qu'il représente. Le comité de gestion est responsable de gérer le programme général et le conseil d'administration révisent et approuvent les budgets et la direction générale du programme. Le secrétariat NEDEM coordonne les comités techniques et leurs programmes respectifs.

La direction du programme a été redéfinie en 1992. Le programme est présenté dans le **Plan de recherche révisé 1992**. Dans le cadre du plan, un groupe de travail a été créé afin de soliciter, d'évaluer et de financer les idées nouvelles qui permettraient de faire avancer la recherche dans le domaine de la prévention et du contrôle du drainage minier acide. Il s'agit du Groupe de travail sur les nouveaux concepts.

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Chairman's Report

This past year, 1992, was a year of revitalization of the MEND program. A thorough review of the program achievements and directions was completed, and a **Revised Research Plan** was presented to the MEND Board of Directors. This plan includes the following new directions for MEND:

- The focus of the program is narrowed;
- The research work will be solicited on a competitive basis;
- The program will spend up to $18 million, and will end in December 1997;
- The projects will be project managed; and
- Innovation and new ideas will be sought and assessed.

The Revised Research Plan was accepted by the Board of Directors in August 1992, and a Memorandum of Understanding was signed by Ministers of 5 governments, representatives of MEND and the Mining Association of Canada in Whitehorse on September 21, 1992. This Memorandum of Understanding committed in principle the partners in MEND to the $18 million program.

Since August 1992, the Management and technical committees have put in place the new Plan by:

- distributing scopes of work for funding commitment;
- preparing requests for proposal for competitive bids;
- establishing a New Ideas Task Force;
- applying project management to all projects; and
- forming an active Technology Transfer committee.

The Management committee representation was expanded to include representatives from the Government of Saskatchewan, the Atomic Energy Control Board, Cape Breton Development Corporation, and Falconbridge Limited. Members from other provinces and Fisheries and Oceans Canada will be sought during 1993. New volunteers have been recruited for all the committees. They are providing the extra vitality needed for MEND to be successful.

Also during 1992, an Intellectual Property Policy was developed and approved for MEND. This policy provides that the Crown (CANMET) will be the custodian of

arising intellectual property on behalf of MEND members. This policy will ensure that technology developed and paid for by MEND members will be available to these members on a royalty-free basis.

The New Ideas Task Force solicited and reviewed proposals for innovative ideas that could result in significant breakthroughs in reducing the liabilities caused by acid mine drainage. Eighty-five proposals were received, and 12 were accepted for up to $10,000 each in "seed" funding to develop proof of concept.

In the area of Prediction, in 1992, there was a new focus on the needs for developing predictive capability for waste rock piles. Although there continues to be an important new understanding developed at several waste rock sites across Canada, the realization that there are important developments abroad led MEND to host a 3-day workshop on waste rock modelling in Toronto in September. This workshop resulted in a plan of action for international cooperation in the development of waste rock models that will reduce the cost of developing the models needed in Canada.

In Prevention and Control, the Peer Review of the underwater disposal program was completed. The results indicate that the disposal of reactive sulphide wastes under water prevents acid generation, but more work is needed to measure the metal fluxes in the water column above the tailings or waste rock. A one-day, technical meeting was held in October with all the stakeholders attending; scientists who did the field work, mining industry representatives, federal and provincial regulators. It was agreed that the work completed to date has been of high quality, and that no fatal flaw in the concept of underwater disposal was evident. Additional work is planned at the underwater disposal sites in Manitoba and British Columbia during 1993.

Wet and dry barriers are also two important areas of work in progress. Projects are underway on the refining of technology to prevent the further oxidation of already oxidized tailings and waste rock. Results to date indicate that composite dry earth covers are very effective, but too expensive for widespread application. Other "dry" covers, such as wood waste, compost, alkaline or depyritized tailings are showing promise in reducing the cost of cover placement and maintenance. Shallow water covers have also shown to be very effective, but additional field and laboratory tests are needed to confirm the low oxidation and metal transport rates.

New disposal technologies for both tailings and waste rock such as elevated water table, porous surround or disposal into flooded open pits are being followed, and results are expected by the end of 1993.

In New Ideas, experiments to evaluate the use of microorganisms to plug off oxygen and water transport into tailings and the use of electrochemistry to

passivate sulphide mineral surfaces were unsuccessful, but the experiments have opened up other technical possibilities that are being followed.

In Treatment, the focus of the work was switched from passive treatments systems to the development of methods to reduce the potential instability of lime treatment sludges.
In Monitoring, MEND has sponsored the adaptation of electromagnetic (EM) methods for the tracking and monitoring of subsurface acidic seepage, and the method has been successfully applied at several sites. The first phase of a waste rock sampling manual was completed, and several environmental impact assessment tools were developed in cooperation with the BC AMD Task Force.

A chairman was appointed to the Technology Transfer committee and the committee prepared and implemented plans on intellectual property, databases, communications and information exchange. International interest in MEND is increasing and the network of contacts in foreign countries was expanded by the International Liaison committee.

The financial commitment to MEND by the mining industry and the government of Canada has remained strong, and the commitment from the provinces continued to improve. Up to December 1992, 77 MEND-sponsored research projects have cost $7.17 million as compared to an approved budget of $8.96 million. The distribution of expenditure among the three partners of MEND is shown in Table 1 and Figure 1.

Tables 2 and 3 list the completed and active MEND-approved projects. Table 4 lists new 1993 projects for which Board approval is requested. These projects will cost $2,979,000, of which $2,565,000 will be spent by the end of 1993, ($414,000 in 1994).

Table 5 lists the proposed 1993 program by program area, and compares the actual and proposed expenditures to the budget defined by the Revised Research Plan.

As of March 1, 1993, funding requirements are:

· Previously approved ongoing projects:	$230,000
· New projects for 1993:	$1,070,000
Total:	$1,300,000

Funding for MEND is an important issue for the Board of Directors to address. Commitment of additional funding is expected in the near future from industrial

and government sources, but all of the above funding requirements may be difficult to obtain. Also, wider participation in MEND projects is needed to compliment the extensive participation by CANMET.

Mineral Development Agreements, in the short term, will be significant sources of funding for MEND. Funds have been notionally allocated to MEND in New Brunswick, Québec, Ontario, Manitoba and British Columbia, and at this time significant funds are available from the federal share of these agreements. However, all Mineral Development Agreements require that there be a contribution from the provinces and the industry, and these matching funds are necessary to maintain the 1/3;1/3;1/3 agreed balance in MEND.

Although the technical, managerial and financial challenges for MEND are numerous, the Management committee is very confident of overcoming these challenges. In 1993, significant progress will be made towards achieving the objectives of MEND and completing the milestones defined in the Revised Research Plan.

Table 1: Contributions to MEND 1988 to 1992 inclusive ($000's)

	Spent (%)	Committed (Approved Projects)	Total (%)
Mining Industry	3,069 (42.8)	298	3,367 (41.6)
Canada	2,449 (34.2)	297	2,746 (33.9)
5 Provinces	1,651 (23.0)	338	1,989 (24.5)
TOTALS	**7,169** (100.0)	**933**	**8,102** (100.0)

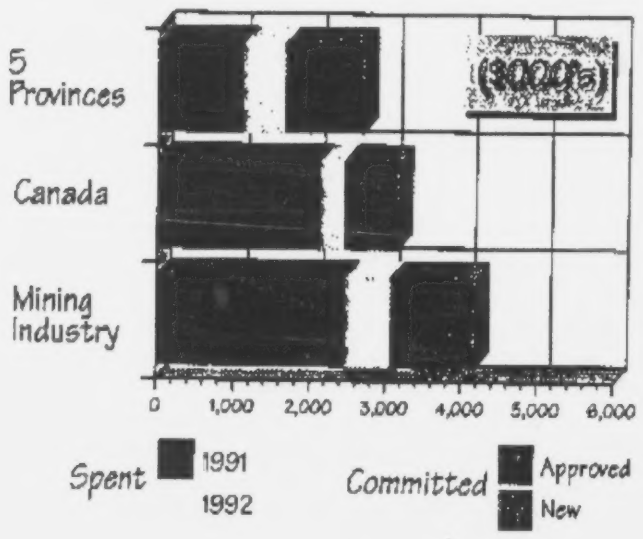


Figure 1: Expenditures by MEND Partners

L'année 1992 a été une année de revitalisation pour le Programme NEDEM. Les comités techniques ont procédé à un examen approfondi des réalisations et des objectifs du Programme, à la suite duquel un **Plan de recherche révisé** a été soumis au Conseil d'administration du NEDEM. Ce plan comprend les changements d'orientation suivants :

- Les objectifs du programme seront mieux circonscrits;

- Il faudra recourir davantage à l'adjudication pour l'exécution des travaux de recherche;

- Le programme aura un budget de 18 millions de dollars et se terminera en décembre 1997;

- Les projets seront gérés par un système de gestion de projet; et

- L'innovation et les nouvelles idées seront encouragées et évaluées.

Le Plan de recherche révisé a été approuvé par le Conseil d'administration en août 1992, et un Protocole d'entente a été signé à Whitehorse le 21 septembre 1992 par les ministres de cinq gouvernements, les représentants du NEDEM et l'Association minière du Canada. Par ce protocole d'entente, les partenaires du NEDEM se sont engagés en principe à participer au programme de 18 millions de dollars.

Depuis août 1992, le Comité de gestion et les comités techniques ont mis en oeuvre le nouveau Plan, ce qui veut dire :

- distribuer aux entreprises des énoncés de travail en vue d'obtenir de leur part des engagements de financement;

- préparer des demandes de propositions sur une base compétitive;

- établir un Groupe de travail sur les nouveaux concepts;

- soumettre tous les projets au régime de gestion de projet; et

- constituer un Comité du transfert de la technologie actif.

Sont maintenant représentés au Comité de gestion le gouvernement de la Saskatchewan, la Commission de contrôle de l'énergie atomique, la Société de développement du Cap-Breton et Falconbridge Limited. On demandera à d'autres provinces et à Pêches et Océans Canada de s'y joindre durant 1993. De nouveaux

volontaires ont étérecrutésdans tous les comités. Ils fournissent le sang neuf dont le NEDEM a besoin pour progresser.

En outre, en 1992, le NEDEM s'est doté d'une politique sur la propriété intellectuelle. Celle-ci établit que la couronne (CANMET) aura la garde, au nom des membres du NEDEM, de toute propriété intellectuelle découlant des travaux de recherche et que les membres du NEDEM pourront utiliser, sans redevance, la technologie qu'ils auront contribué à développer et à financer.

Le Groupe de travail sur les nouveaux concepts a sollicité et révisé des propositions d'idées pouvant faire avancer la recherche en vue de réduire le fardeau financier lié au drainage minier acide. Il a reçu et examiné 85 propositions et en a accepté 12. Des montants de départ allant jusqu'à 10 000 $ ont été accordés à leurs auteurs pour qu'ils démontrent la valeur du concept proposé.

En 1992, dans le domaine de la prévision, on s'est intéressé aux besoins d'élaborer des modèles pour prévoir le drainage minier acide des stériles. Bien que les recherches progressent sur ce point grâce aux études menées au Canada dans plusieurs parcs, des progrès importants réalisés à l'étranger ont poussé le NEDEM à tenir un atelier de trois jours sur la modélisation des stériles à Toronto en septembre. À la suite de l'atelier, on a préparé un plan d'action en vue d'établir un programme de coopération internationale qui diminuera le coût de l'élaboration des modèles de prévision au Canada.

Dans le domaine de la prévention et du contrôle, l'examen, par un comité de pairs, du programme de disposition subaquatique a été terminé. Les résultats indiquent que la disposition subaquatique des rejets sulfureux semble offrir des avantages contre la production des eaux acides, mais qu'il faut travailler encore à trouver les moyens de mesurer le flux des métaux dans la colonne d'eau qui recouvre les résidus ou les stériles. Une réunion technique d'une journée s'est tenue en octobre avec tous les groupes concernés : les chercheurs qui ont fait le travail de terrain, les représentants de l'industrie minière et les organismes de réglementation fédéraux et provinciaux. Les participants ont convenu que le travail accompli jusqu'à présent était de très grande qualité et que le concept de la disposition subaquatique ne présentait apparemment aucune lacune majeure. D'autres études doivent avoir lieu en 1993 sur des sites de confinement au Manitoba et en Colombie-Britannique.

Des travaux importants se poursuivent également au sujet des barrières humides et sèches. Des projets sont en cours pour améliorer la technologie servant à freiner l'oxydation des résidus et des stériles. Les résultats obtenus jusqu'à présent indiquent que les barrières sèches stratifiées sont très efficaces, mais coûtent trop cher pour qu'on puisse les utiliser à grande échelle. L'utilisation de matériaux différents tels que les résidus forestiers, le compost, les résidus alcalins ou dépyritisés permettrait probablement de réduire le coût d'installation et d'entretien des barrières. Les barrières humides peu profondes se sont avérées très efficaces, mais il faut encore faire des essais sur le terrain et en laboratoire pour confirmer qu'ils ont bien pour effet de diminuer les taux d'oxydation et de transport des

métaux.

Des technologies nouvelles de disposition des résidus et des stériles, telles que l'élévation de la nappe phréatique, l'utilisation de structures poreuses périphériques ou le confinement dans des fosses inondées, sont à l'étude; on espère avoir des résultats en 1993.

Dans le domaine des nouveaux concepts, des expériences ont été effectuées afin de vérifier l'efficacité de l'obturation microbienne pour stopper le transport de l'oxygène et de l'eau à travers les résidus, de même que l'utilisation de l'électrochimie pour passiver les surfaces de minéraux sulfurés. Malgré des résultats peu heureux, ces expériences ont ouvert d'autres possibilités techniques que l'on étudie actuellement.

Dans le domaine du traitement, on a délaissé les systèmes de traitement passif au profit des méthodes visant à réduire l'instabilité potentielle des boues à la chaux.

Dans le domaine de la surveillance, sous l'égide du NEDEM, des méthodes électromagnétiques (EM) ont été adaptées à la localisation et à la surveillance des eaux souterraines acidifiées. L'expérience a été concluante, et on les a utilisées dans plusieurs sites. La première étape de la préparation d'un guide d'échantillonnage de stériles est achevée et plusieurs outils d'évaluation des effets environnementaux ont été mis au point en coopération avec le *Acid Mine Drainage Task Force* de la Colombie-Britannique.

Un nouveau président a été nommé au sein du Comité du transfert de la technologie. Le Comité a préparé et établi des plans concernant la propriété intellectuelle, les bases de données informatisées, les communications et l'échange d'information. L'intérêt international pour NEDEM augmente et le réseau de contacts avec les pays étrangers s'est étendu grâce au Comité de liaison internationale.

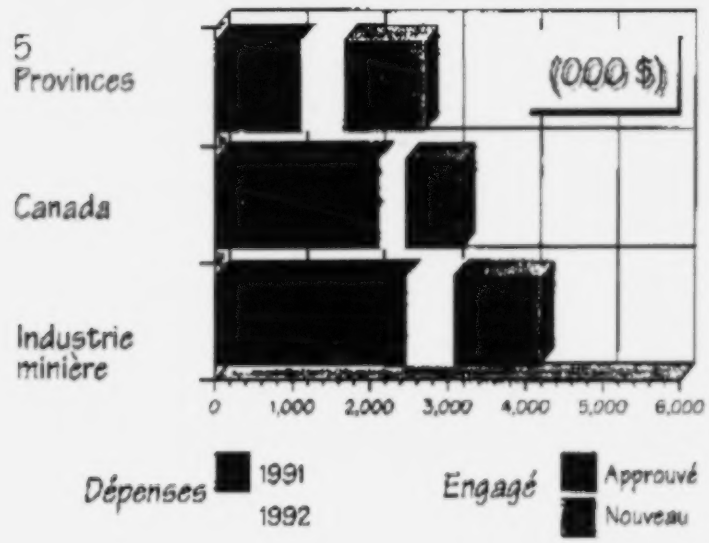
La participation financière de l'industrie minière et du gouvernement canadien au Programme demeure importante. Celle des provinces a continué d'augmenter. Jusqu'en décembre 1992, 77 projets de recherche financés par le NEDEM ont coûté 7,17 millions de dollars, sur un budget approuvé de 8,96 millions de dollars. Le Tableau 1 et la Figure 1 montrent la répartition des dépenses entre les trois partenaires du Programme.

Tableau 1 : Contributions à NEDEM de 1988 à 1992 inclusivement (000$)

	Dépenses (%)	Sommes engagées (projets approuvés)	Total (%)
Industrie minière	3 069 (42,8)	298	3 367 (41,6)

Canada	2 449 (34,2)	297	2 746 (33,9)
5 provinces	1 651 (23,0)	338	1 989 (24,5)
TOTAUX	**7 169** (100,0)	**933**	**8 102** (100,0)

Figure 1: Dépenses des Partenaires NEDEM



Les tableaux 2 et 3 énumèrent les projets terminés et en cours dans le cadre du NEDEM. Le Tableau 4 énumère les nouveaux projets de 1993 qui doivent être approuvés par le Conseil. Ces projets coûteront 2 979 000$, desquels 2 565 000$

seront dépensés d'ici la fin de 1993
(414 000$ en 1994).

Le Tableau 5 montre le programme proposé pour 1993 selon les domaines du programme et compare les dépenses actuelles et proposées au budget défini dans le Plan de recherche révisé.

Les besoins financiers pour 1993, établis au 1er mars 1993, sont les suivants :

- projets en cours approuvés 230 000 $
- nouveaux projets de 1993 1 070 000 $

Total : 1 300 000 $

Le financement du NEDEM est une question importante pour le Conseil d'administration. On s'attend à ce que les gouvernements et l'industrie s'engagent à verser au Programme d'autres fonds dans un proche avenir, mais les effets des restrictions budgétaires se feront sans doute sentir. De plus, une participation accrue de l'industrie dans les projets NEDEM est nécessaire pour compléter la participation importante de CANMET.

Les ententes sur l'exploitation minérale (EEM) devront constituer une source de financement importante à court terme. Des fonds ont été alloués au NEDEM au Nouveau-Brunswick, au Québec, en Ontario, au Manitoba et en Colombie-Britannique, et des sommes importantes peuvent encore être prélevées sur la part fédérale du budget de ces ententes. Toutefois, toutes les ententes sur l'exploitation minérale exigent que l'industrie et les provinces fournissent une contribution importante, et il faudra recourir à ces fonds pour faire en sorte que l'investissement dans le NEDEM soit réparti, comme convenu, à parts égales entre les trois partenaires.

Bien que les défis techniques, financiers et de gestion soient nombreux pour NEDEM, le Comité de gestion est très confiant que des progrès importants nous rapprocheront des objectifs du NEDEM et nous permettront, en 1993, de franchir les étapes définies dans le Plan de recherche révisé. Pour y parvenir, il faudra surmonter des difficultés techniques et financières, mais les nombreux volontaires et participants du NEDEM sont convaincus de pouvoir le faire.

Table 2: Completed Projects

Project	Title	Budget ($000's)	Expenditures ($000's)	Variance ($000's)	Sponsors ($000's)
1.11.1	AMD from Waste Rock - Literature Review	50	50	0	Env. Can. (25), Teck (25)
1.14.1	Field Evaluation Rock Hydrogeochemistry - Mine Doyon	362	362	0	Québec (94), Lac (134), Cambior (134)
1.15.1	AMD from Open Pits - Equity Silver	55	53	2	B.C. (10), CANMET (10), Placer Dome (33)
1.16.1a	Evaluation of Prediction Techniques - Tailings & Waste Rock	70	63	7	CANMET (63)
1.16.1b	Manual of Chemical Evaluation Procedures	23	23	0	CANMET (23)
1.16.1c	Development of Static Evaluation Procedures	40	21	19	CANMET (21)
1.17.1	Hydrogeochemical Investigation - Waite Amulet	235	285	(50)	CANMET (117), Noranda (168)
1.21.1a	Evaluate RATAP.BMT Capabilities	30	30	0	CANMET (30)
1.21.1b	Workshop of Modelling Techniques - Tailings	70	73	(3)	CANMET (63), Falconbridge (10)
1.21.1c	Prepare RATAP Users Manual	30	19	11	Env. Can. (19)
1.24.1	Development of Preliminary Modelling of Seepage Quality from Acid-generating Waste Rock Dumps	285	21	264	DIAND (21)
1.41.1	International Workshop on Waste Rock Modelling	10	7.7	2.3	CANMET (0.5), Noranda (0.8), Falconbridge (0.8), Québec (0.8), INCO (0.8), DIAND (0.8), HBM&S (0.8), Ontario (0.8), Teck (0.8), B.C. (0.8)
2.11.1a	Evaluation of Existing Underwater Disposal Sites	210	220	(10)	B.C. (50), CANMET (70), HBM&S (65), Env. Can. (35)
2.11.1b	Evaluation of Existing Underwater Disposal Sites	250	136	114	B.C. (5), CANMET (5), HBM&S (50), Env. Can. (26), Placer Dome (50)
2.11.1c	Evaluation of Existing Underwater Disposal Sites	50	68	(18)	Placer Dome (67.6)
2.11.1d	Peer Review on the Subaqueous Disposal of Tailings	45	34	11	CANMET (32.4), Placer Dome (2)
2.14.1	Establish Vegetative Wetlands Over Tailings	100	30	70	Falconbridge (25), CANMET (5)
2.21.1	Engineered Dry Covers for Tailings	230	216	14	Env. Can. (61), CANMET (35), DSS (120)
2.22.1	Assessment of Hardpan	150	100.5	49.5	Manitoba (101)
2.23.1	Documentation of Disposal Methods - Tailings & Waste Rock	75	75	0	B.C. (38), CANMET (37)
2.23.2a	Thickened Tailings Disposal (TTD) Method	60	67	(7)	Falconbridge (67)
2.24.1	Vegetation Manual	35	33.5	1.5	CANMET (34)
2.31.1a	Dry Covers on Waste Rock - Heath Steele	400	312	88	BM&S (172), New Brunswick (140)
2.32.1	Blending and Segregation of Waste Rock - Kutcho Creek	140	140	0	Sumac (110), B.C. (15), CANMET(15)
2.32.2a	Co-disposal of Tailings and Waste Rock - Mines Selbaie	96	96	0	Québec (76), CANMET (20)
2.33.1	ARD Remediation Measures at Four Norwegian Mines	38.5	38.5	0	B.C. (19.3), Norway (19.3)
2.41.1a	Electrochemical Oxidation/Passivation of Sulphides	60	60	0	HBM&S (10), Lac (10), Noranda (5), CANMET (35)
2.44.1	Microbial Plugging	100	100	0	CANMET (60), INCO (10), Noranda (20), Teck (10)
3.11.1a	Treatment of Acidic Seeps Using Wetland Ecology and Microbiology	230	281	(51)	INCO (166), CANMET (40), Denison (25) Env. Can. (50)
3.11.1b	Treatment of Acidic Seeps Using Wetland Ecology and Microbiology	250	273	(23.4)	INCO (83), CANMET (90), Denison (30) Env. Can. (70)
3.11.1c	Treatment of Acidic Seeps Using Wetland Ecology and Microbiology	128	125	0	Env. Can. (27), CANMET (27), Québec (30) INCO (25), Denison (16)
3.12.1a	Assessment of Existing Natural Wetlands	40	40	0	Env. Can. (40)
3.21.1a	Metals Recovery from Acid Mine Drainage	25	25	0	CANMET (10), Env. Can. (15)

4.1.1	Field Methods Manual - Tailings	20	29	(9)	CANMET (29)
4.3.1	Standard Reference Materials - Tailings	50	50	0	CANMET (50)
4.5.2	Field Sampling QA/QC	9.5	9.5	0	Noranda (9.5)
4.7.1	Optimum Sampling Frequency	27	27	0	B.C. (13.5), CANMET (13.5)
4.7.2	Biological Monitoring of Acid Mine Drainage	21	21	0	B.C. (10.5), CANMET (10.5)
4.7.3	Aquatic Invertebrate Monitoring	136	136	0	B.C. (75), CANMET (42), Env. Can. (4), Noranda (15)
4.7.4	Acid Mine Drainage Sediment Monitoring	6.5	6.5	0	B.C. (4), CANMET (2.5)
4.7.5	Ion Speciation	35	35	0	B.C. (6), CANMET (6), Noranda (23)
4.7.6	Paleolimnology Techniques	16.5	16.5	0	Noranda (16.5)
5.4.1	ARD Technical Guide - version française	24	24	0	Québec (23.7)
5.5.1	Preliminary MEND Research Plan	25	25	0	CANMET (25)
5.6.1	Second International Conference on the Abatement of Acidic Drainage	127	127	0	CANMET (30), Teck (8), Env. Can. (15), Cominco (5), Rio Algom (4), Falconbridge (4), Placer Dome (4), INCO (11), Noranda (20), Cambior (4), MITEC (7), HBM&S (3), Ontario (7), B.C. (3), MAC (2), Québec (10)
	Totals	4,470	3,984.7	485.3	01/03/93

Table 3: Active Projects

Project	Title	Approved Budget ($000's)	Expenditures ($000's)	Variance ($000's)	Sponsors ($000's)
1.12.1	Compile AMD Prediction Data - Tailings & Waste Rock	45	25	20	B.C. (33), CANMET (12)
1.14.2	Monitoring & Modelling AMD from Waste Rock - Mine Doyon Phase II	450	201	249	Lac (75), Cambior (75), Québec (150), CANMET (50)
1.19.1	Kinetic Tests for Cinola Gold Project	100	64	36	Env.Can. (47), B.C. (25), City Res. (2.4), CANMET (20)
1.21.1d	Beta Evaluation of RATAP.BMT3	15	3	12	CANMET (15)
1.22.1	ANSTO Model at Heath Steele	145	26	119	N.B. (25), Noranda (65), CANMET (85)
1.23.1	Compilation of Rules for the Prediction of AMD	30	10	20	B.C. (5), CANMET (5)
1.25.1a	Development of a Soil Flux Model to Design Tailings Covers	49.5	49	0.5	CANMET (56)
1.26.1	Development of Modelling Methodology for Prediction of Seepage from Acid-generating Waste Rock	90	30	60	Env. Can. (30), B.C. (60)
1.31.1	Fundamental Reaction Kinetics - SIMS	95	51	44	Echo Bay (5), DIAND (18), Ontario (53), INCO (14)
1.32.1	Prediction and Prevention of ARD - A Geological & Mineralogical Approach	73	70	3	Env. Can. (55), Teck (3), HBM&S (3), BHP (3), Placer Dome (3), Cominco (3), Homestake (3)
2.13.1	Flooding of Existing Tailings Sites - Quirke Lake	835	835	0	Rio Algom (502), CANMET (333)
2.13.2	Flooding of Existing Tailings Sites - Solbec Cupra	260	157.8	102.2	Cambior (58.4), CANMET (30), Québec (69.4)
2.21.2	Engineered Dry Covers for Tailings - Noranda	348	419	(71)	CANMET (136), Noranda (157), Québec (126)
2.22.2	Evaluation of Dry Covers Built from Mine Tailings	234.9	127.9	107	Québec (121.9), Ste-Geneviève (6)
2.23.3	Porous Envelope - Falconbridge	123	123	0	Falconbridge (70.2), Ontario (52.8)
2.25.1	Reclamation of Tailings using Municipal Solid Waste Compost		130	56	74 Falconbridge (43.5), Ontario (32.5)
2.31.1b	Dry Covers on Waste Rock - Heath Steele	367.7	246	121.7	Noranda (121.3), N.B. (91.9), CANMET (154.5)
2.35.2a&b	Lysimeter Covers for Waste Rock	145	120.5	24.5	Noranda (92.7), Québec (52.3)
2.42.1a	Synthetic Polymers	83	31	52	INCO (22.5), Ontario (22.5)
3.11.1d	Treatment of Acidic Seeps Using Wetland Ecology and Microbiology	80	60	20	Env. Can. (20), CANMET (20), Québec (20), INCO (20)
3.12.2	Evaluation of Panel Wetlands	45	45	0	CANMET (22.5), Ontario (22.5)
3.13.1a	Treatment of Small Seeps	90	90	0	Noranda (60), CANMET (30)
3.21.1b	Removal of Metals - Ion Exchange	75	4	71	Teck (10), Falconbridge (4), Ontario (25)
3.21.2a	Removal of Metals - Chemical	100	90	10	Noranda (90)
3.31	Use of Lime Sludges for Capping	20	5	15	INCO (6.7), CANMET (6.7), Ontario (6.7)
4.2.1	Decommissioning Criteria	15	0	15	Ontario (5), HBM&S (5), Homestake (5)
4.5.1	Field Methods Manual for Waste Rock (Phase I & II)	100	24	76	CANMET (24), AECB (10), INCO (25), Homestake (10)
4.5.3	ARD Technical Guide Revision - Monitoring Section	50	0	50	CANMET (50)
4.6.1	Geophysical Monitoring Methods	118	68	50	CANMET (38), Ontario (38), INCO (54.5)
4.6.2	Continuous Monitoring of AMD - Literature Review	50	28	22	Québec (47)
4.8.1	Monitoring of the Flooded Solbec Pit	139	109	30	CANMET (30), Québec (130)
5.3.1	Laurentian Database	35	35	0	Ontario (35)
	Totals	4,536.1	3,203.2	1,332.9	

01/03/93

Table 4: Projects Recommended for Board Approval

Project	Title	Proposed Budget ($000's)	Funds Required ($000's)	Commitments/Comments ($000's)
1.15.2	AMD from Open Pits - Expansion & Verification of Model	150	150	Industrial support at two sites sought
1.31.2	Residual Weathering Production Waste Rock Dumps	40	10	B.C. (20), Placer Dome (10)
1.32.2	Pyrite Oxidation - Lithological & Mineralogical Factors	40	10	B.C. (20), Placer Dome (10)
1.41.2	ARD Waste Rock Monitoring Database	20	0	CANMET (20)
1.42.1	Critical Review of Geochemical Modelling	40	0	Ontario (20), CANMET (20)
1.43.1	Physical Waste Rock Modelling - Coordination	70	70	---
1.51.1	Quantitative Analysis of Chemical & Biological Kinetics	12	0	Env. Can. (12)
1.51.2	Nonlinear Modelling for Chemical Kinetics for AMD	34	0	Env. Can. (34)
2.12.2	Evaluation of Existing Underwater Sites - 1993 Program	300	250	Placer Dome (50)/ HBM&S (?)
2.15.1	Water Covers - Laboratory/ Field	487	259	Noranda (228), request for funds distribution for remainder
2.20.1	Evaluation of Alternate Dry Covers	50	20	CANMET (15), Ontario (15)
2.21.2	Engineered Dry Covers for Tailings - Noranda	121	9	Noranda (62.8), CANMET (25), Québec (24.1) (increase in scope, budget to 469)
2.23.2b	TTD - Kidd Creek (Year 2)	89	0	Falconbridge (89)
2.23.2c	TTD - Tracer Study	78	0	Falconbridge (39), Ontario (20), CANMET (20)
2.23.2d	TTD - Geochemical Study	250	0	Falconbridge (125), Ontario (63), CANMET (63)
2.25.2	Wood Waste Cover - East Sullivan	431	80	Québec (351), request for funds distributed for remainder
2.34.1	Cementitious Cover - Westmin	130	0	Westmin (100), CANMET (30)
2.35.2c	Lysimeter Covers for Waste Rock	50	0	Noranda (18), Québec (32) (increase in scope, budget to 195)
2.45.1a	Separation of Sulphides	75	35	Ontario (20), CANMET (20)
3.13.1b	Small Seeps - Field Evaluation	60	60	Go/No Go after evaluation of laboratory data
3.21.3	Removal of Metals - Pilot Tests	65	65	Go/No Go after evaluation of laboratory data
3.22.1	AMD - Water Quality Survey	11.5	11.5	Request for funding distributed
3.32.1	Lime Treatment - Process and Sludges	60	0	CANMET (30), Ontario (30)
4.6.3	Remote Monitoring - Techniques Review & Manual	60	0	Ontario (30), CANMET (30)
4.8.2	Sediment Sampling Probe Field Application	51	0	CANMET (17), Ontario (17), INCO (5), Falconbridge (12)
5.3.2	Expand Databases at Laurentian & UBC	40	40	---
5.6.2	Third International Conference on Abatement of Acidic Drainage	15	0	CANMET, Lac Minerals, Ontario, Others
5.7.1	MEND Newsletter	3	0	CANMET (3)
5.8.1	Economic Evaluation of MEND-developed Technology	30	0	CANMET (30)
6.1	New Ideas Solicitation	120	0	CANMET (30), DIAND (9.2), HBM&S (10), INCO (10), Lac (10) Noranda (16), Québec (20), Ontario (5), Teck (10)
	Totals	2,982.5	1,069.5	

01/03/93

Table 5: 1993 MEND Program and Budget

Committee	Program Area	Total Budget Revised Research Plan ($000's)	Spent & Committed ($000's)	Proposed 1993 ($000's)	Committed 1993 ($000's)	Needed ($000's)	
Prediction	Chemical Prediction	1,314	1,006	-----	-----	-----	
	Modelling	2,501	830	280	60	220	
	Basic Research	388	163	80	60	20	
Prevention & Control	Underwater Disposal	1,393	458	300	50	250	
	Wet Barriers	1,955	1,023	487	228	259	
	Dry Barriers	2,673	1,049	602	493	109	
	Waste Rock	2,110	1,100	180	180	-----	
	Other	1,150	395	492	457	35	
Treatment	Wetlands	1,104	914	60	-----	60	
	Lime System	625	149	137	60	77	
Monitoring		1,125	804	111	111	0	
Technology Transfer		362	211	88	48	40	
New Ideas & Innovation		1,300	-----	162	162	0	
Totals		18,000	8,102	2,979	1,909	1,070	01/03/93

1.0 Introduction

The prediction of acidic drainage from waste rock became a focus of attention in late 1991, and this has been reflected in the emphasis that the Prediction committee has placed on waste rock modelling during 1992. A significant activity in this area was the International Waste Rock Modelling Workshop that was held in Toronto in late September. The workshop recommendations, which are discussed in more detail below in section 1.2, have enabled the committee to better define the modelling program for 1993.

The interpretation of chemical prediction test results remains an issue for MEND, particularly in correlating laboratory results to field observations. A number of continuing studies address the issue although there were no new projects initiated in this area in 1992. However, it is understood that for effective predictive capabilities, there is an need to further develop testing procedures and integrate both chemical tests and mathematical modelling.

During 1992, the MEND program put an increased effort towards the development of new and innovative techniques to prevent acid mine drainage. Within the Prediction program this has translated into a preliminary mathematical assessment of potential nonlinear and chaotic conditions that may be associated with the kinetics of acid generation in mine wastes.

The preliminary results of the projects highlighted under Basic Research which started in 1992 generated considerable interest. During 1993, these projects will be completed and plans have been made to further the micro-scale investigations of weathering products and processes, and the assessment of oxidation rates as they relate to overall deposit characteristics.

1.1 Chemical Prediction

A total of seven chemical prediction projects have been completed. The output of these projects include; a manual of chemical prediction techniques; an evaluation of these techniques using both tailings and waste rock; and, recommendations for predictive technique improvements. The first phase of a comprehensive multi-year field evaluation program of the hydrogeochemistry of a large (21 million tonne) waste rock pile at Mine Doyon is complete. Additional data, which continues to be collected, form the basis of the second phase, that has a more predictive modelling approach (1.14.2). Similarly, the completed project on the acidic drainage from open pits has laid the foundation for a second phase which is part of the recommended 1993 program for predictive modelling (1.15.2).

In 1993, several other projects will be completed. A 1992 review of the Cinola Gold project (1.19.1) resulted in recommendations which redefined the scope for the third and final year. In 1993, the monitoring of the Cinola Gold waste rock material will be finished and include final data collection and the analysis and comparison of field and laboratory predictive data collected over the past 6 years. Compilation of AMD predictive data will also continue into 1993, and a reassessment of the database software being used will be completed. In the very near

future, the committee will examine the needs for additional development of static/kinetic testing capabilities.

Table 6: Chemical Prediction

Complete		**Budget($)**
1.11.1	AMD From Waste Rock - Literature Review	50k
1.14.1	Field Evaluation Rock Hydrochemistry - Mine Doyon	362k
1.15.1a	AMD From Open Pits - Equity Silver	53k
1.16.1a	Evaluation of Predictive Techniques	63k
1.16.1b	Manual of Chemical Evaluation Procedures	23k
1.16.1c	Development of Static Evaluation Procedures	21k
1.17.1	Hydrogeochemical Investigations - Waite Amulet 1985/90	285k
Active		
1.12.1	Compile AMD Prediction Data	45k
1.19.1	Kinetic Tests for Cinola Gold	100k
1.23.1	Compilation of Rules for the Prediction of AMD - New Mines	30k
Associate		
	Interpretation of Kinetic Tests for Predicting the Quality of Mine Tailing Effluents.	

1.2 Modelling

The overall objective of the modelling program is to develop the predictive tools needed to effectively manage acid-producing waste rock and tailings areas and develop closure techniques. The prediction of acid generation in waste rock presents challenges greater than those encountered in tailings, due in part to particle size, rock heterogeneity, and the unsaturated nature and porosity of piles. As indicated earlier, 1992 saw a shift in priority from chemical techniques to predictive modelling, and within this, an increased emphasis on waste rock versus tailings.

The predictive tailings model RATAP.BMT3 is commercially available. Further development of this model within the MEND program is not being considered, however an external evaluation (ß-evaluation) was initiated to identify and address any operational problems. The capacity to determine moisture fluxes between tailings, cover systems and the atmosphere was developed and the Soil-Atmosphere Flux model, based on routine climate data and soil properties, will be available in 1993.

The development of an applied or empirical waste rock model is being based largely on what is already known to control oxidation and acid generation. The report for the first phase of this program is under review and will be finalized by mid-1993. The specific issues of gas and heat transport mechanisms in waste rock piles are being addressed through the application of a computer model developed in Australia, to the Heath Steele site in New Brunswick. This project will remain active through 1993. A very reactive (acid) waste rock pile at Mine Doyon in Québec, has presented an excellent opportunity to study a waste rock dump in detail. Building upon the monitoring program started in the first phase, geochemical, physical and hydrological processes are being studied in detail and predictive techniques to simulate these processes are being developed.

A three day international workshop on modelling the generation and transport of acid rock drainage from mining waste was organized through the Prediction committee and held at the end of September, 1992. The purpose of the workshop was to focus model development by identifying industry and regulatory requirements, gaps in current capabilities, and available international expertise. Representatives of the participating countries (Canada, Australia, Norway, Sweden, and the United States) concluded that a useable model should incorporate: oxygen and heat transport; solute and water movement; and geochemistry. The capacity to simulate oxygen and heat transport within a waste rock dump is, for the most part, already available. The science of solute transport under mainly unsaturated conditions is less advanced, while the geochemical processes are considered to be the most difficult to effectively simulate.
The committee has recommended a series of projects for 1993 as part of the development program for waste rock modelling defined at the workshop. The projects will include a critical review of applicable geochemical processes and associated modelling capabilities. This will permit an assessment of the degree to which these processes can be confidently incorporated into a modelling scheme.

Table 7: Predictive Modelling

Complete		**Budget($)**
1.21.1a	Evaluate RATAP.BMT2 Capabilities	30k
1.21.1b	Workshop on Modelling Techniques	73k
1.21.1c	Prepare RATAP User's Manual	19k
1.24.1	Development of Preliminary Modelling of Seepage Quality from Acid-Generating Waste Rock Dumps	21k
1.41.1	International Workshop on Waste Rock Modelling	8k
Active		
1.14.2	Monitoring & Modelling AMD from Waste Rock - Mine Doyon Phase II	450k
1.21.1d	Beta-Evaluation of Tailings Model - RATAP.BMT3	15k
1.22.1	ANSTO Model at Heath Steele	145k
1.25.1	Soil Atmosphere Flux Model to Design Tailings Covers	50k
1.26.1a	Development of Modelling Methodology for Prediction of Seepage Quality from Acid-Generating Waste Rock	90k
Recommended for 1993		
1.15.2	AMD From Open Pits-Expansion/Verification of Model	150k
1.41.2	ARD Waste Rock Monitoring Database	20k
1.42.1	Critical Review of Geochemical Modelling	40k
1.43.1	Physical Waste Rock Modelling - Coordination	70k

1.3 Basic Research and New Ideas

Knowledge gained from fundamental research on acid generation continues to play an important and necessary role in advancing predictive capabilities. Surface-sensitive techniques such as SIMS (Secondary Ion Mass Spectrometry), XPS (x-ray photoelectron spectroscopy), and AES (Auger Electron Spectroscopy) are currently being used in the delineation of weathering mechanisms occurring at or near the surfaces of pure minerals and waste rock. Further assessment of residual weathering products in waste rock dumps, composition, stability etc., will be carried out through 1993.

The integration of geological and mineralogical characteristics of wastes into the assessment of acid-generating potential is considered imperative. Formulae for assessing this potential based on the entire prevalent mineral assemblages are being developed. As an extension to this work (1.32.1), the assessment of rock types having similar acid generation potential but differing oxidation rates will be furthered in 1993.

Finally, in the area of New Ideas, the Prediction committee proposes to address the issue of nonlinear and chaotic conditions associated with the kinetics of acid generation and neutralization in mine waste. If found to be significant, more attention will needed to be focused in this area of mathematical modelling.

Table 8: Basic Research and New Ideas

Active		**Budget($)**
1.31.1	Fundamental Reaction Kinetics Study of Weathering Employing SIMS	95k
1.32.1	Prediction and Prevention of Acid Rock Drainage - A Geological and Mineralogical Approach	73k
Recommended for 1993		
1.31.2	Residual Weathering Products in Waste Rock Dumps	40k
1.32.2	Pyrite Oxidation - Lithological & Mineralogical Approach	40k
1.51.1	Quantitative Analysis of Chemical and Biological Kinetics	12k
1.51.2	Nonlinear Modelling of Chemical Kinetics for AMD	34k

2.0 Introduction

The Prevention and Control (P&C) committee has sub-divided its research programs into five main areas: underwater disposal, wet barriers, dry barriers, waste rock and others. A sub-committee chairman was nominated for each area based on that person's involvement and/or expertise in the area.

2.1 Underwater Disposal

Early in the MEND program, consensus had been developed that placing acid-generating materials underwater would prevent sulphide oxidation, (underwater disposal is defined as the placement of fresh, unoxidized tailings underwater).

A work plan was developed in 1989, which consisted of evaluating four lakes where tailings had been placed over two year periods for each lake. A preliminary evaluation and geochemical assessment on the interstitial water was completed (Project 2.11.1ab) on three of the four lakes. In 1992, the work on Benson Lake (Project 2.11.1c), completed the fourth lake (Table 9). The project focused on the chemical and biological aspects of changes in Benson after subaqueous tailings disposal. Keogh Lake, located 12 km upstream from Benson was used as a control for water chemistry, sediments and biota analyses to permit geochemical comparison.

In 1992, the major focus of the subaqueous disposal project was the completion of a Peer Review that followed a recommendation of the Board of Directors in 1991. The review had two objectives: to provide technical and scientific assessment of MEND studies on subaqueous disposal of tailings; and to outline additional requirements necessary for the MEND studies to maintain a credible scientific approach. The final report was received in August 1992 and contained several recommendations which needed to be assessed before proceeding with more work.

The report identified key areas of information deficiency. For instance, the studies of background limnologies for the lakes were not adequate to present to regulatory personnel; the seasonal and yearly changes that occur in the water column loadings needed to be addressed; the field experiment for metal flux measurements, although well done, did not assess the quantitative fluxes which are considered important. Some additional literature reviews (e.g. metal toxicology) and a complete program for documenting QA/QC were suggested and the definition of the types of additional field data (e.g. geochemical) and methods for data collection were recommended.

An orientation session to fully describe the progress and potential of subaqueous disposal to provincial and federal regulatory personnel, held in Winnipeg in October provided positive feedback on the merits of the subaqueous disposal method. Consequently, additional research should proceed to provide additional information needed to support the application of this method.

In order to use the wide range of resources available to achieve maximum credibility in the future work and to accelerate the research to achieve the capability to use subaqueous disposal, a planning team of technical/scientific experts has been assembled by the sub-committee chairman. This team, which met in January 1993, outlined a study program for the next 3 to 4 years which incorporated the recommendations made in the peer review and a specifically focused application scenario. Two of the original four lakes were selected to continue the field program and work to complete the geochemistry database is to begin in March 1993 at Anderson and in the summer at Buttle. The estimated cost for this study program is $1.8 million, greatly exceeding the Revised Research Plan budget of $0.6 million. The underwater disposal sub-committee will review the proposed program needs, costs and predicted outputs and make recommendations to the Management committee early in 1993.

Table 9: Underwater Disposal Projects

Completed Projects		**Budget($)**
2.11.1a	Evaluation of Existing Underwater Disposal Sites - 1988/89 Program	220k
2.11.1b	Evaluation of Existing Underwater Disposal Sites - 1990 Program	136k
2.11.1c	Evaluation of Existing Underwater Disposal Sites - 1991/92 Program	67.6k
2.11.1d	Peer Review on the Subaqueous Disposal of Tailings	34.4k
Recommended for 1993		
2.11.2	Evaluation of Existing Underwater Disposal Sites - 1993 Program	300k
Associate Project		
	Study of Submarine Ocean Tailings Disposal	

2.2 Wet Barriers

As distinct from underwater disposal, wet barriers refers to establishing water cover on oxidized tailings. As with underwater disposal, continued oxidation is considered unlikely but the mobilization of the soluble salts becomes a major

consideration. The proposed closure plans for several Canadian tailings sites call for water covers. The P&C committee is following three national and one international project on flooding of existing tailings sites.

Research into the effects of flooding tailings continued at both the Quirke Lake and Solbec Cupra sites in 1992. A piping failure in November 1990 and a leak in a dam foundation in late 1991 had prevented the flooding of the 65 hectares experimental test site at Quirke. Repairs were completed and flooding commenced in November 1991, and observations in 1992 confirmed that the flooding of test section is being maintained. The report on the completion of the laboratory and field results is 2 years behind schedule. The 1992 Solbec Cupra program involved the installation of another basin where lime was added to the oxidized tailings and the monitoring of field lysimeters. Work planned for 1993 includes the completion of a synopsis report for the Quirke project, and further tests on the chemical and microbiological effects of flooding and the optimum depth of water cover required to prevent resuspension of tailings solids at Solbec Cupra.

A laboratory and field test program to simulate the movement of total acidity and metal loadings from oxidation products under different flow regimes (i.e. surface and groundwater) and to predict treatment requirements was started in 1992, and work on the determination of diffusion coefficients and metal fluxes has started. Work on the oxygen diffusion characteristics, the wave action and sediment erosion characteristics and contaminant transport flux measurements are planned for 1993. One of the objectives of this project is to establish evaluation techniques and standardized laboratory procedures so that the results could be modelled and the future impact predicted for the flooding option.

Table 10: Wet Barriers Projects

Completed Project		**Budget($)**
2.14.1	Establish Vegetative Wetlands Over Tailings	30k
Active Projects		
2.13.1	Flooding of Existing Tailings Sites - Quirke Lake	835k
2.13.2	Flooding of Existing Tailings Sites - Solbec Cupra	260k
Recommended for 1993		
2.15.1	A Study on Water Covers for the Decommissioning of Mine Waste Disposal Sites	487k
Associate Projects		
	Flooding of Existing Tailings Sites - Falconbridge	
	Flooding of Existing Tailings Sites - Stekenjokk, Sweden	

2.3 Dry Barriers

The use of dry barriers to prevent further oxidation and/or transportation of oxidation products, has been the subject of considerable investigation. The cover materials evaluated to date in laboratory and in companion field studies include composite clay/soil covers and plastic membranes (Waite Amulet). The aim of properly designed composite covers is to maintain a saturated layer which prevents the transfer of oxygen. It has been found that these covers also effectively limit water transport through the cover. One of the issues that must be addressed with dry barriers is freeze/thaw, which is the reason for the increase in scope for the Waite Amulet project in 1993 (Table 11).

When clay or low permeability soils are not readily available at many sites, alternate materials having somewhat similar properties may be substituted. A project started in 1992 is evaluating, in the laboratory, mine tailings as an alternative material for covers. Two other projects are evaluating organic covers which may function to limit oxygen penetration but not water penetration. It is perceived that the organic materials will create a strongly reducing layer due to the continuing degradation of the organic material. The first project involves the use of compost and the second wood waste.

While dry covers do reduce the penetration of oxygen and/or water into the tailings, they may be too expensive, too short term or the needed materials may not be locally available. The committee proposes that a study be undertaken in 1993 to prepare a ranking of the potential alternate cover materials that could be further considered. This project (2.20.1) was not identified in the Revised Research Plan but it is considered to be a critical study for the dry barriers area. The budget for this work has been transfered from proposed additional work on microbial plugging (2.44.1).

Table 11: Dry Barriers Projects

		Budget($)
Completed Projects		
2.21.1	Engineering Dry Covers for Tailings - Laboratory	216k
2.22.1	Assessment of Hardpan	101k
2.23.1	Documentation of Disposal Methods - Tailings and Waste Rock	75k
2.24.1	Vegetation Manual	34k
Active Projects		
2.21.2	Engineered Dry Covers for Tailings - Noranda	348k
2.22.2	Evaluation of Dry Covers Built from Mine Tailings	235k
2.25.1	Reclamation of Sulphide Tailings Using Municipal Solid Waste Compost	130k
Recommended for 1993		
2.20.1	Evaluation of Alternate Dry Covers for the Prevention of Acid Mine Drainage from Tailings	50k
2.21.2	Engineered Dry Covers for Tailings - Noranda (increase in scope)	121k
2.25.2	Design of an Organic Barrier Using Wood Waste - East Sullivan	431k
Associate Project		
	Engineered Dry Covers for Tailings - Curragh	

2.4 Waste Rock

Although some of the cover techniques available for tailings may be applicable to waste rock, the circumstances and methods are different. Waste rock is much less homogeneous than tailings and much more permeable. Waste rock piles have the potential for developing induced air flows due to temperature gradients and porosity. Also the potential for differential settlement in the piles may be greater with waste rock than tailings.

The dry cover options are likely limited to natural covers, plastic membranes or cementitious materials. As with dry covers on tailings, the cost effectiveness of any cover must be evaluated as must the life expectancy and integrity of those covers.

Monitoring of the Heath Steele composite clay/soil cover continued in 1992. Information on the rate of oxygen and moisture infiltration through the cover, and temperature and oxygen profiles within the pile are being collected for performance evaluation. Initial results show the cover to be very effective in preventing acidic drainage; two more years of monitoring remain in this project.

The project on blending and segregation at Kutcho Creek was completed in 1992. The study determined that the blending of Kutcho waste rock would not be a viable option and that the cost associated with a full-scale waste dump would be excessive.

Two other projects were completed in 1992. The Mines Selbaie co-disposal project was terminated after the first phase because the low sulphur content tailings were found to be acid-generating. The Norwegian remediation measures review project was also completed and is now being reviewed by MEND prior to publishing.

The Management committee recommends the approval of two waste rock projects. The first project, the lysimeter study at Noranda Technology Centre is concerned with evaluating several waste rock management techniques in specially-constructed lysimeters built for this purpose. The second year of monitoring has been completed and the most effective method of controlling acid generation was water cover, followed by 3% limestone addition. An interim report was received in December 1992 and is being reviewed. Approval is being requested to complete additional modelling of geochemical processes associated with the different measures being investigated. The second project recommended for approval is a cementitious cover project to demonstrate the long-term effectiveness of a large-scale shotcreted cementitious cover as a means of reducing acid production in waste rock dumps.

Table 12: Waste Rock Projects

Completed Project		**Budget($)**
2.31.1a	Dry Covers on Waste Rock - Heath Steele	312k
2.32.1	Blending and Segregation of Waste Rock - Kutcho Creek	140k
2.32.2a	Co-disposal of Tailings and Waste Rock in Cells at Les Mines Selbaie	96k
2.33.1	ARD Remediation Measures at Four Norwegian Mines	39k
Active Projects		
2.31.1b	Dry Covers on Waste Rock - Heath Steele	368k
2.35.2a&b	Lysimeter Evaluations of Cover Alternatives - Noranda	145k
Recommended for 1993		
2.34.1	Use of Cementitious Covers to Control Acid Generation at Westmin's HW Mine - Shotcrete Field Trial	130k
2.35.2c	Lysimeter Evaluations of Cover Alternatives - Noranda (increase in scope)	50k
Associate Projects		

2.5 Others

This area covers the work that does not logically fit into the other four areas. A general area of research that is identifiable is pre-treatment. This includes chemical, or physical treatment that could prevent acid generation in either the short or long term. Physical treatments such as electrochemical passivation or use of a synthetic polymer are examples of physical pre-treatments that have received some attention. The concept of sulphide separation is also being pursued by the committee as a pre-treatment option that could open up several economical disposal options if successful. The separation of sulphides project would evaluate various conventional mineral processing technologies that could be applied to the separation of sulphides in tailings and evaluate the relationship between sulphide elimination and acid generation and the operating costs of these options.

The laboratory test program to evaluate the microbial plugging of tailings was completed in 1992. It concluded that a microbial cap would not significantly reduce the permeability of the tailings over long periods of time and that the addition of bacteria to the tailings was not necessary because native strains are already present. No further work is planned.

Existing and new innovative tailings and waste rock disposal methods in terms of their effectiveness in controlling acid production is another area that is being investigated. Two projects on the examination and documentation of different types of tailings disposal methods were continued in 1992. The two methods being examined are porous envelope and thickened tailings discharge.

Electromagnetic surveys, techniques developed under the Monitoring program, were used successfully at Falconbridge's porous surround project to identify the groundwater contamination plumes thus saving considerable cost in the installation of monitoring equipment. Results from Phase (a) of the study of the thickened tailings discharge (TTD) methods indicate that the TTD is advantageous because of the low dissolved metal fluxes to the environment. Additional work is recommended for a better understanding of the effectiveness of the system in the long term.

Table 13: Others

		Budget($)
Completed Projects		
2.41.1a	Electrochemical Oxidation/Passivation of Sulphides - Small Scale Scoping Studies	60k
2.23.2a	Hydrogeological and Geochemical Analysis of TTD System at Kidd Creek	67k
2.44.1	Microbial Plugging of Mine Tailings to Reduce the Production of AMD	100k
Active Projects		
2.42.1	Development of Synthetic Polymers - Laurentian	83k
2.23.3	Porous Envelope Surrounding Tailings - Falconbridge	123k
Recommended for 1993		
2.23.2b	Hydrogeological and Geochemical Analysis of TTD System at Kidd Creek	89k
2.23.2c	A Tracer Study of Fluid and Contaminant Movement in the Upper Surface of the TTD System at Kidd Creek	78k
2.23.2d	Geochemical Evaluation of the TTD System at Kidd Creek	250k
2.45.1a	Separation of Sulphides from Mill Tailings - Phase I	75k

3.0 Introduction

The Treatment committee met in 1992 in Sudbury, Ontario, Kimberley, B.C., and Bathurst, New Brunswick, to review active and new research projects and to refine the treatment component of the Revised Research Plan. Field meetings proved useful in retaining members' interest and in more clearly focusing the research needs.

There were five active treatment projects during 1992; the continuation of the engineered wetlands work at Sudbury, the examination of a natural wetland, two projects on the recovery of metals from acid mine drainage, and a small project on the polymerization of lime treatment sludge.

3.1 Wetlands and Treatment of Small Seeps

A project on the application of wetland ecology and microbiology (engineered wetlands) has been underway for 4 years at Sudbury and earlier at Elliot Lake. This project has been a controversial one, with costs to date exceeding $740,000. The first 2 years of this project had been subject to a peer review, and the project was found, subject to some minor revisions, to be technically sound. Although good water quality continued to be produced, at the beginning of 1992 it became apparent that the capacity of the system was far below original predictions. The committee carefully reviewed the project and decided that stopping the project would have wasted most of the previous expenditures and it was therefore recommended that the project continue one more season under strict project management control. A final report, which will be completed at the end of March 1993, will detail the performance and applicability of the system.

The experimental work was completed on the mechanisms and performance of a natural wetland in treating acidic drainage at the Panel mine site in Elliot Lake. A final report will be completed at the end March 1993. Because of the presence of submerged tailings, the results are expected to be very important for the design of shallow water covers. An associate MEND project at Bell Copper that uses an engineered wetland to treat a mild, copper-contaminated acidic drainage continued to produce very good water quality results.

The laboratory phase of the evaluation of other small seep treatment technology was completed. In general, these technologies developed in Canada and the United States use sulphate-reducing bacteria (SRB's) and alkaline solids to treat small volumes of seepage, but have been only been successfully applied to mild or low-

acidity seeps. The results indicate that a combination of more than one of these methods may be needed for application at many Canadian metal-mining sites.

Before proceeding with the proposed field tests on any additional passive treatment systems, the process-limiting factors of reaction rates at low temperatures (2 to 10°C) and the rates of nutrient and bacteria nutrient addition will be examined by the Treatment committee.

3.2 Metals Removal From AMD

A study had been completed in 1991 on effluent treatment technology that might compliment or replace the conventional lime treatment system. The study concluded that there was little economic potential to completely replace the lime neutralization system, but that the instability and potential toxicity of lime sludges were priority research targets. It was therefore necessary to develop metals removal techniques that would precede lime treatment in the process stream. Three technologies were indicated as showing promise; copper cementation, selective precipitation of metals, and ion exchange.

In 1992, laboratory scale projects were started on ion exchange and on the selective precipitation of metals. Both projects will be completed mid 1993, and small scale pilot scale testing of one of the methods will be started.

3.3 Lime Treatment and Sludge Stabilization

The major emphasis for the balance of the MEND Treatment program in this area will be the review of technology and production of a manual on lime treatment, and the determination of methods to stabilize treatment products. In 1993, a contract will be let to review the state-of-the art of lime treatment, and to outline research needs on treatment sludge stabilization.

A small project was initiated at Laurentian University on the production of a stable polymer using lime treatment sludge as one part of the ingredients.

Table 14: Treatment

Complete		**Budget($)**
3.11.1a-c	Treatment of Acidic Seeps Employing Wetland Ecology and Microbiology - 1988-91	608k
3.12.1a	Assessment of Existing Natural Wetlands Affected by Low pH, Metal Contaminated Seepages - 1990	40k
3.21.1a	Metals Recovery from Acid Mine Drainage	25k
Active		
3.11.1d	Treatment of Acidic Seepages Employing Wetland Ecology and Microbiology - 1992	80k
3.12.2	Evaluation of Wetlands at the Panel Dam "A" Site	45k
3.13.1a	Treatment of Small Seeps	90k
3.21.1b	Metals Removal from Acid Mine Drainage - Ion Exchange	75k
3.21.2a	Metals removal from Acid Mine Drainage - Chemical	100k
3.31	Use of Lime Sludges for Capping	20k
Recommendations for 1993		
3.13.1b	Treatment of Small Seeps - Field	60k
3.21.3	Removal of Metals from AMD - Pilot Tests	65k
3.22.1	Survey of Acid Mine Drainage Characteristics	12k
3.32.1	Lime Treatment - Review and Sludge Stabilization	60k
Associate Projects		
	Field Evaluation of Acid Mine Water Treatment Using Constructed Wetlands at the Halifax Airport	
	Constructed Wetland at Noranda Bell Mine	
	Treatment of Acidic Seepage Using Chinese Alders	

4.0 Introduction

In this age of technology development, monitoring capabilities are continuing to improve. For MEND, the questions that must be answered are: which of the techniques being developed and/or becoming commercially available are applicable to the monitoring of acidic mine drainage; and how, or to what extent, should they be applied during the mining, decommissioning and closure stages.

Definition of standard sampling methods and programs and assessment of new technologies for rapid, indirect monitoring are the priorities which were emphasized by the Monitoring committee in 1992, and will continue to be emphasized in 1993.

4.1 1992 Activities

The work completed through the BC AMD Task force in 1992 was concerned with the development or assessment of environmental impact assessment tools. Projects on use of a trough-like apparatus for aquatic invertebrate monitoring, analyses of environmental impact through sediment sampling, biological monitoring, and the potential of paleolimnology techniques for establishment of biological baselines were completed. Also, a model to project the most probable ionic speciation of elements in mine effluents has been developed.

A summary review of waste rock sampling procedures was completed in 1992. This was the first of two phases in the preparation of a field sampling manual for waste rock, a more complex undertaking than that for tailings.

The monitoring of the effect of water quality of waste rock placed in the Solbec Pit was continued through 1992. Because of the discovery of the migration of contaminated water, the installation of additional boreholes was recommended and an electromagnetic survey of the site will be done to optimize their placement. This survey will be undertaken in the spring of 1993. A comprehensive compilation and review of established decommissioning criteria by Canadian and specific American regulatory agencies was initiated in 1992. Also, a revision of the monitoring chapter of the Draft B.C. Acid Rock Drainage Technical Guide was initiated and is expected to be finished early in 1993. The first draft of the guide, originally completed in 1989 covered, but did not adequately address monitoring. Conclusions and recommendations from completed and current MEND and B.C. Task Force monitoring studies will be incorporated in the revised chapter.

Also initiated in 1992 were a background review of existing intrusive continuous monitoring technologies, and an assessment of geophysical monitoring methods. Continuous effluent monitoring may be useful under certain circumstances, and the former project involves an international review of available technologies to meet these requirements. The latter project involves the application of four geophysical methods to detect and assess subsurface migration of acid mine drainage. These methods appear to have considerable potential for reducing the cost of monitoring acid mine drainage.

4.2 1993 Program

A method for locating and measuring subsurface contaminated discharges which can be obscured by overlying surface water has been developed. In 1993 an evaluation of use of this sediment probe will be tested at two sites in Ontario for determining the location of submerged acidified groundwater discharge zones. Success of the probe for acid mine drainage associated applications will be measured in terms of sensitivity, reliability and associated cost.

The second phase in the generation of a field methods manual for waste rock will be initiated this year and the work is proposed to include the following steps: augmentation of the phase I review by assessing the techniques listed, resultant data, estimated cost, and reproducibility; recommendation of key sampling procedures which will be assessed at an experts workshop; and finalization of a methods manual based on the phase I review, external surveys, and the experts workshop.

Finally, in 1993, the Monitoring committee will identify and evaluate available remote sensing techniques applicable to the monitoring of acid mine drainage. For the purpose of this work, the term 'remote' is meant to include a range of monitoring technology, hand held devices through to satellite imagery. A methods manual will be produced describing the techniques and their appropriate applications, as well as recommendations for further development of one or more of the most applicable techniques.

Table 15: Monitoring

Complete		**Budget($)**
4.1.1	Field Methods Manual - Tailings	29k
4.3.1	Standard Reference Materials - Tailings	50k
4.5.2	Field Sampling QA/QC	10k
4.7.1	Optimum Sampling Frequency	27k
4.7.2	Biological Monitoring of AMD	21k
4.7.3	Aquatic Invertebrate Monitoring	136k
4.7.4	AMD Sediment Monitoring	7k
4.7.5	Ion Speciation	35k
4.7.6	Paleolimnology Techniques	17k
Active		
4.2.1	Decommissioning Criteria	15k
4.5.1	Field Methods Manual - Waste Rock	100k
4.5.3	ARD Technical Guide Revision - Monitoring Section	50k
4.6.1	Assessment of Geophysical Monitoring Methods	118k
4.6.2	Continuous Monitoring of AMD - Literature Review	50k
4.8.1	Monitoring of the Flooded Solbec Pit	139k
Recommended for 1993		
4.6.3	Remote Monitoring Techniques - Review	60k
4.8.2	Sediment Sampling Probe Field Application	51k
Associate		
	Remote Sensing to Monitor Uranium Tailings Sites - AECB	

5.0 Introduction

Technology Transfer is a very significant activity for the MEND program, and strong effort in this area is needed if the objectives are to be achieved. The Technology Transfer committee became active in 1992. Mr. Michael Sudbury was appointed chairman of the committee and new members were recruited.

5.1 Databases

One of MEND's major objective is to collect and distribute information on acid mine drainage so that MEND members can keep informed of emerging technologies and to reduce the chances of duplication in research programs. A bilingual database has been established as part of Laurentian University's Mining Environment Database. The database includes a complete bibliographic description of titles as well as abstracts of papers and publications on acidic drainage. In addition, actual documents are available in the Laurentian Library for consultation or for borrowing through interlibrary loan.

Early in 1993, the committee will review the functioning and usefulness of the Laurentian Database and make recommendations for improvements. Also the committee will review proposals for the establishment of a complimentary database at the University of British Columbia.

5.2 Intellectual Property

In August 1992, the MEND Board of Directors decided that Arising Intellectual Property would be vested with the Crown, and a new policy was prepared. The Technology Transfer committee will ensure that the new policy is implemented.

5.3 Communications

MEND presentations were made during the year at:

West Virginia Surface Mine Drainage, Task Force Symposium, Morgantown,W.V.;
Environment Issues and Management of Waste in Energy and Mineral Production, Calgary, Alberta;
Guidelines for ARD Prediction in the North Workshop, Yellowknife, NWT;
Ontario Environmental Research and Technology, Technology Transfer Conference, Toronto, Ontario.

Also, the chairman of the MEND Board and Management committees made presentations on the achievements of MEND and the Revised Research Plan to senior mining and government officials in Québec City, Toronto, and Vancouver.

5.4 Publications

MEND reports are distributed by CANMET. Once a report is completed, abstracts and order forms are circulated to MEND participants and to individuals and libraries who are interested in receiving copies of MEND reports. A 500 name mailing database is maintained by the MEND Secretariat. A list of MEND reports currently available is shown in Appendix F.

5.5 Project Activities - Technology Transfer

Many new initiatives are proposed for 1993 in order to keep MEND participants informed of the progress and results of the program. In addition to the publications in CIMM and other journals, a MEND Newsletter will be published three times a year. MEND will co-sponsor with the U.S. Bureau of Mines the Third International Conference on the Abatement of Acidic Drainage in Pittsburgh in April 1994. The Technology Transfer committee will help ensure that the MEND profile and quality of papers at this conference is high. Workshops on acid mine drainage are planned for Sudbury and Val-d'Or in 1993.To make certain that technology developed by MEND is affordable, methods for economic evaluation of this technology will be developed and applied.

Table 16: Technology Transfer

Complete		**Budget($)**
5.4.1	Acid Rock Drainage Technical Guide - version française	24k
5.5.1	Preliminary MEND Research Plan	25k
5.6.1	Second International Conference on the Abatement of Acidic Drainage	127k
Active		
5.3.1	Laurentian Database	35k
Recommended for 1993		
5.3.2	Expand Databases at Laurentian & UBC	40k
5.6.2	Third International Conf. on the Abatement of Acidic Drainage	15k
5.7.1	MEND Newsletter	3k
5.8.1	Economic Evaluation of MEND-developed Technology	30k
Other Initiatives		
	Report Distribution by CANMET	
	Seminars, Workshops and Conference Presentations	

6.0 Introduction

International interest in MEND remains strong. Nowhere else in the world is there a national coordinated effort on industrial wastes that matches the industry-government cooperation and technical focus of MEND. Certainly acid-producing mine wastes are ubiquitous throughout the world, and many countries are looking to Canada for leadership in finding affordable and technically sound solutions.

International Liaison is not formalized into a committee, but is instead an informal network of contacts through the MEND Secretariat and technical committees

6.1 Activities

The principle activity during 1992 was an international workshop in September on waste rock modelling that was organized by the Prediction committee. This 3-day workshop brought together scientists, engineers and regulators from Australia, United States, Sweden, Norway and Canada to discuss the predictive techniques needed for acid-producing waste rock. This workshop resulted in the implementation of a plan of cooperation that will be carried out over the next 3 years.

Cooperation remained strong with agencies and individual scientists in the United States. Over 20 individuals from the United States participate in MEND technical committees as full or associate members. Important technical developments in the United States in chemical predictive techniques, dry covers and passive water treatment systems are being closely monitored by MEND.

International liaison will be expanded in 1993 to include contacts in other countries such as Japan, Finland, South Africa, and member states of the European Community, in particular Germany where there are extensive acid-generating uranium and coal mine wastes in the former GDR.

In cooperation with the U.S.Bureau of Mines, MEND will play a leading role in the Third International Conference on Acidic Drainage, planned for Pittsburgh in April 1994.

7.0 Introduction

The Revised Research Plan of 1992, approved by the MEND Board in August 1992, requires that about 15% of the remaining expenditures be allocated to soliciting and funding new ideas and innovation. The resulting technology would be:

- inexpensive to implement and maintain;
- broadly applicable across Canada;
- long-lasting;
- different from current known methods of preventing and controlling acidic drainage;

and/or

- result in very significant reduction in the cost of application of known technology.

7.1 Solicitation of New Ideas and Innovation

It was determined that both the slowness of the MEND approval process, and the concern about ideas being incorporated into existing projects or programs was an impediment to entrepreneurs and scientists in bringing forth their ideas for consideration by MEND. The Management committee recommended that a Task Force with a time-limited mandate be established to solicit new ideas and innovation. Mr. Ken Wheeland was appointed to facilitate this Task Force which is a 5-member team including 3 university professors from outside MEND. The mandate of this Task Force is to:

- solicit up-front funding from MEND members;
- solicit proposals from proponents, with emphasis on universities (in the first round);
- evaluate proposals and provide seed funding (up to $10,000) for review or development of concepts;
- select project champions and manage contracts; and
- evaluate the results and recommend further action, if any.

A simple concise proposal format was developed and distributed across Canada by mail, and at workshops held at 5 universities. Limited time was given to the proponents to respond to the request for proposals.

7.2 Results of Solicitation

In the six weeks allocated to the proponents, 85 proposals were received from across Canada. These proposals were evaluated and 10 proposals were accepted for funding, and these are listed in Table 17. Two other projects, Status of U.S. Research, and Permafrost, were accepted for funding and put in place early in the mandate of the Task Force.

Table 17: New Ideas Projects Accepted for Funding

New Ideas #	Title	Proponent	Budget($)
0	Status of U.S. Research	Tarassoff	6.2k
01	Permafrost	Geocon	9.2k
05	Low Cost Petroleum Product Cover	CANMET	10k
15	Chelating Ribbon	University of Manitoba	10k
17	Chemically Modified Clay	Alberta Research Council	10k
28	Artificial Hardpan	CANMET	10k
31	Ion Exchange Resin	McGill University	10k
58	Phosphate Coating	Université Laval	10k
65	Sulphide Passivation	Technical U. of Nova Scotia	5k
69	Comingling of wastes	UBC	10k
73	Japanese Technology	Laurentian University	10k
83	Chelating/Filtering of AMD	Zenon	10k
		Total	**110.4k**

7.3 New Ideas - 1993 Program

Most of the projects will be complete by mid 1993, and the Task Force will evaluate the results of the projects and recommend to the Management committee which projects, if any, should be supported further by MEND.

If further support is justified, the project will be incorporated into the technical committee work plans. Each project has an assigned "champion" at the proof-of-concept stage. A second round of proposal solicitation is proposed for September-October 1993, and this round will focus on proposals from entrepreneurs and research institutions. Proposals from outside Canada will also be considered.

Six other proposals that had some technical merit, were referred to the appropriate technical committee for further consideration. In general, the project proposals focused on new ways of treating acid mine drainage, rather than the desired emphasis on prevention and control.

APPENDIX A

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Mr. W. Fraser

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Mr. D.G. Feasby — Manager, MEND Secretariat, CANMET

Mr. M.P. Filion	Director, Environmental Affairs, Teck Corporation
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APPENDIX B

Projects Completed Before 1992 **March 1993**

Number	Titles:
1.11.1	AMD from Waste Rock - Literature Review
1.14.1	Field Evaluation Rock Hydrochemistry - Mine Doyon
1.15.1	AMD from Open Pits - Equity Silver
1.16.1a	Evaluation of Predictive Techniques - Tailings & Waste Rock
1.16.1b	Manual of Chemical Evaluation Procedures
1.16.1c	Development of Static Evaluation Procedures
1.17.1	Hydrogeochemical Investigation - Waite Amulet
1.21.1a	Evaluate RATAP.BMT2 Capabilities
1.21.1b	Workshops of Modelling Techniques - Tailings
1.21.1c	Prepare RATAP Users Manual
1.24.1	Development of Preliminary Modelling of Seepage Quality from Acid-Generating Waste Rock Dumps
2.11.1a,b	Evaluation of Existing Underwater Disposal Sites
2.14.1	Establish Vegetative Wetlands Over Tailings
2.21.1	Engineered Dry Covers for Tailings
2.22.1	Assessment of Hardpan
2.23.1	Documentation of Disposal Methods - Tailings and Waste Rock
2.24.1	Vegetation Manual "Manual of Methods Used in the Revegetation of Reactive Sulphide Tailings Basins"
2.31.1a	Dry Covers on Waste Rock - Heath Steele
3.12.1	Assessment of Existing Natural Wetlands
3.21.1a	Metals Recovery from Acid Mine Drainage
4.1.1	Field Methods Manual - Tailings
4.3.1	Standard Reference Materials - Tailings
4.7.1	Optimum Sampling Frequency
4.7.2	Biological Monitoring of Acid Mine Drainage
4.7.4	Acid Mine Drainage Sediment Monitoring
5.5.1	Preliminary MEND Research Plan

PREDICTION

Project 1.11.1: AMD from Waste Rock - Literature Review
Expenditures:$50,000

A critical review of existing information on acid-generating waste rock was carried out. Relevant information on theory, experiments, modelling and field studies were assessed for their validity and applicability. The impact of various construction techniques on phase migration, solid, liquid, and gas, were assessed. Water movement and solids migration within rock piles were found to be dependant on hydraulic conductivity, hydraulic gradients, degree of saturation, and laminar versus turbulent flow. Solids migration was defined in terms of internal migration and geotechnical failures, and gas transport, primarily through gaseous advection. The primary reactions were identified as: acid generation, which may be driven by abiotic and biological factors; acid neutralization; and metal leaching. Acid neutralization is a highly complex series of aqueous and mineral reactions. Speciation analyses were identified as useful but under-utilized. The parameters associated with the rate and extent of metal leaching were identified and discussed.

Project 1.14.1: Field Evaluation Rock Hydrochemistry - Mine Doyon Phase I
Expenditures:$362,000

Initial dump characterization of the 21 million tonne Mine Doyon waste rock pile in Québec was carried out through review and evaluation of all available site documentation. Indepth characterization (physical, chemical and hydrological) was done using: boreholes penetrating the entire thickness of the rock pile and into the bedrock; boreholes along the perimeter to sample groundwater; exploration pits to observe alteration phenomenon; and weir stations in the drainage ditches to measure water flow. An inventory and assessment was made of all granular material available for use as a (composite) dry cover, but although suitable materials were identified, differential compaction in the dump due to weathering does not favour the installation of a natural cover. Based on heat and mass balances it is estimated that 7000 tonnes of pyrite ($<1\%$ of total) oxidize per year and that the amount of pyrite in the dump has not been significantly depleted. Temperature profiles indicate that oxidation is in a steady state and may be maintained for at least another 100 years. More detailed studies related to prediction are planned (1.14.2). A comparaison of mineralogical content with leachate chemistry will help understand reactions of leachate formation and transformation.

Project 1.15.1: AMD from Open Pits - Equity Silver
Expenditures:$53,000

The overall objectives were to assess relative contributions of AMD sources in open pits and to develop an applicable computer model of such a system. All relevant information on water movement and chemistry on and within mine walls was reviewed. Acidic conditions appear to be at least partially due to unsaturated fractures. The rates of acid generation and neutralization on exposed pit walls of the Main Zone Pit at Equity Silver in British Columbia were determined using field studies and existing mine data. The importance of detailed baseline studies of groundwater prior to mining was emphasized. Metal leaching is strongly dependant on aqueous speciation and mineral solubility. A computer code, MINEWALL was created to simulate open pits during operation and decommissioning and applied using site-specific information. In the case of Equity Silver, it was predicted that the flooded pit would return to neutral after the initial acid flush. MINEWALL has undergone preliminary verification but is not ready for general use. Further development is planned (1.15.2).

Project 1.16.1a: Evaluation of Predictive Techniques
Expenditures:$63,000

To predict the generation of acid mine drainage from mine wastes, there are several methods available of varying complexity. These methods have been evaluated to assess their reliability when applied to the field and to recommend those with the most promise for determining the potential for generating acid drainage. The following documented chemical prediction static and kinetic procedures were evaluated and compared: B.C. Research Initial test; Acid Base Accounting; Sulphur Ratio test; H_2O_2 for Pyrite Estimation; B.C. Research Confirmation test; Humidity Cell test; Shake Flask Weathering test; Soxhlet Extraction test; and Manometric Carbonate Pressure Analysis. In addition three more recently developed tests were evaluated: Net Acid Production test; Modified Biological Confirmation test; and Modified Acid Base Accounting. Evaluations were carried out by performing each procedure on eight tailings samples and four waste rock samples from Canadian mines. The advantages and limitations of each method are discussed. The documentation of the above procedures in a detailed users manual format was recommended (1.16.1b).

Project 1.16.1b: Manual of Chemical Evaluation Procedures
Expenditures:$23,000

A user's guide has been produced for the application of chemical evaluation procedures (identified in 1.16.1a) for the prediction of acid generation from mining wastes and related materials. The manual provides background information on acid generation from mine wastes and applicable references. An integrated approach to acid mine drainage prediction strategy is also outlined. Guidelines to the application of the individual prediction tests, details of procedures and associated considerations are addressed. The balance of the manual is devoted to the detailed descriptions of recommended and alternative chemical predictive procedures. Six static (short term) methods and five kinetic (long term) methods are described. For each method, the applicability, objectives, advantages and disadvantages are discussed. The test principles, equipment and reagent requirements, test procedure interpretation and manner of result reporting are outlined in detail. To date there is no single chemical predictive method that is applicable to all waste materials and/or situations. Further development is seen as essential to meet predictive needs (1.16.1c).

Project 1.16.1c: Development of Static Evaluation Procedures
Expenditures:$21,000

As part of the overall program to identify and evaluate techniques for predicting the potential for tailings and waste rock to produce contaminated run-off and seepage, further applicable static procedures were identified and assessed. Based on a review of the chemical literature four methods were ranked by among other parameters: cost; rapidity and robustness; and selected for preliminary testing using samples of known mineralogical composition. The methods tested were: determination of sulphur as pyrrhotite and pyrite; field determination of sulphur as pyrite; modification of the conventional U.S. EPA neutralization potential procedure by filtration of leachate and addition of hydrogen peroxide; and determination of carbonates by metal analysis. The first procedure performed well but further development of the latter three was considered necessary. Methods to directly and quantitatively determine Ca and Mg carbonates are not commercially available and modification of the third procedure is recommended to address this problem. It was underlined that routine acid-base accounting should include a supporting mineralogical description to provide confidence in the predictive chemical results.

Project 1.17.1: Hydrogeochemical Investigation - Waite Amulet Reactive Tailings
Expenditures:$285,000

This multi-year hydrogeochemical baseline field study was designed to develop a better understanding of the hydrology and hydrogeochemistry occurring in acid-generating tailings ponds. The data were also collected to be used to assess/refine existing predictive models (1.21.1a) and provide guidance in the development of new models and control techniques. Preliminary site reconnaissance along with piezometer installation and sampling of tailings and pore water allowed an assessment of the tailings and underlying hydrogeologic characteristics such as pore water chemistry, water table and tailings depth, mineralogy, hydraulic conductivity, direction of flow, and biological activity data. Further data collection completed the definition of the site hydrogeology. The unsaturated zone geochemistry under clay covered, directly vegetated and untreated sites and along the dam face was evaluated. Oxidation control options were defined. A water and metal balance for the tailings site was completed by monitoring precipitation, evaporation, and the flow and quality of the seepage at the face and the surface. The mineralogy of the unsaturated zone was defined and related to pore water chemistry using computer models. Oxygen diffusion versus depth into the tailings was determined. The study verified that the most important control on pyrite oxidation is the availability of oxygen, which influences production of ferric iron and bacterial population density. Oxygen diffusion was considered horizontally as well as vertically.

Project 1.21.1a: Evaluate RATAP.BMT2 Capabilities
Expenditures:$30,000

Originating from work in the mid 1980's by CANMET, the Reactive Acid Tailings Assessment Program for Base Metal Mines (RATAP.BMT) was developed as a predictive modelling tool to: investigate the parameters which control sulphide mineral oxidation in tailings; simulate such acid generation; estimate acid generation potential in the long term; and evaluate control measures. The capabilities and limitations of the RATAP.BMT2 model were evaluated, including calibration of the model using Waite Amulet field data (1.17.1) and critical assessment of the concepts on which the model is based. Part of the data was used to calibrate the site dependent parameter estimates and the rest to verify the model both in the temporal and spatial sense. Modifications were made to the model where required. The modelled constituents included: temperature; pH; oxygen

concentration with depth; and porewater concentration of sulphate, ferrous and ferric iron, dissolved copper and zinc. Further review of the model has been made (1.21.1b) and with more recent revisions,a manual has been generated (1.21.1c) for the current version, RATAP.BMT3.

Project 1.21.1b: Workshops of Modelling Techniques - Tailings
Expenditures:$73,000

An international workshop was held on modelling of reactive tailings, to assess the current capabilities and the perceived requirements (industrial, regulatory). The workshop was held in Haliburton, Ontario on May 23 & 24, 1990, and was attended by participants from Canada, Sweden, United States, and Australia, representatives from the mining industry, the consulting community, universities and various governmental departments. The presentations and discussions concentrated on the simulation model, RATAP.BMT2, capable of calculating the generation of sulphuric acid from reactive tailings. Other presentations provided a consulting engineering perspective, the industry perspective and the point of view of the regulatory agencies for the use of models. Finally, representatives of the United States, Sweden and Australia presented their assessment of current capabilities. The use of programmed models capable of calculating the characteristics of reactive tailings and their impact on the environment was discussed. It was recommended that the RATAP.BMT2 predictive model should be made available to potential users for evaluation before more development of the model was undertaken, and that a users manual should be made available with the model (1.21.1c).

Project 1.21.1c: Modelling of Reactive Tailings - Prepare RATAP Users Manual
Expenditures:$19,000

The mathematical model, Reactive Tailings Assessment Program (RATAP), was designed to predict, in the long-term, the quantity of acid generated by oxidation of pyrite in uranium mill tailings. This model was adapted to base metal tailings, and at the international modelling workshop in May of 1990 (1.21.1b), it was recommended that the model be prepared for distribution to potential users for application to AMD sites. RATAP.BMT3 is a complex model with over 250 input parameters, not lending itself to easy use. Therefore a module to facilitate inputting initial condition data and a second module to facilitate the acquisition and display of output data from model simulations were developed. This combination provides a powerful user-friendly predictive tool. A user's manual was prepared for the software ensemble. As recommended, an overview document has been prepared for RATAP.BMT3 to assist the potential user. This has been prepared, not as a separate document but as part of the input module, giving an overview of the models intended purpose and applications, estimated simulation capabilities,

limitations, and expansion potential. Both model and manual are being distributed through the Canada Centre for Mineral and Energy Technology (CANMET).

Project 1.24.1: Development of Preliminary Modelling of Seepage Quality from Acid-generating Waste Rock Dumps.
Expenditures:$21,000

The project was originally scoped to follow the complete development and abandonment of a 15 million tonne dump, over the course of four years. A variety of factors led to a much reduced scope of work, although it was recommended that the predictive modelling of AMD from waste rock be pursued. Collection and description of selected drill core samples from the Yukon (Curragh Resources) were carried out on site for dump material characterization. Key physical and chemical parameters were identified for the monitoring of reactive waste dumps. A conceptual model of the physical and geochemical nature of waste dumps was developed based on the existing literature and the incorporation of the parameters above. The development of such a model was recommended and would guide future assessment and design of instrumentation requirements for reactive waste rock dumps (1.26.1). The complexity of the modelling effort and potential scope of the study has however, been recognised.

PREVENTION AND CONTROL

Project 2.11.1a&b: Evaluation of Existing Underwater Disposal Sites
Expenditures:a: $ 220,000 b: $ 136,000

The objective of this project was to evaluate the effectiveness of underwater disposal of reactive wastes by evaluating representative existing sites, by examining the impacts which result when in-lake disposal systems are used, and recommending criteria for the safe underwater disposal of tailings. Initially (2.11.1a), all known Canadian sites were documented and water quality results obtained from existing sources (1988/89). Field surveys were done on 4 sites during the summer of 1989 (Buttle and Benson Lakes in B.C., Anderson and Mandy Lakes in Manitoba). Geochemical assessments were conducted at Anderson and Mandy Lakes in Manitoba in 1990 (2.11.1b). In order to more fully understand these systems, and to develop comprehensive conclusive case history information, additional technical supportive work was recommended.

Project 2.14.1: Establish Vegetative Wetlands over Tailings

Expenditures:$ 30,000

The objective of this project was to develop a technique for the reclamation of high iron sulphur tailings by establishing a marshland or perched water table above the tailings. The project was initiated in 1986, when a total of 9 test cells with different surface covers and amendments were constructed at the Fault Lake tailings site in Falconbridge. The covers were kept wet and the porewater quality and metal loading of the unoxidized tailings were monitored for three field seasons. Two important recommendations resulted from this study: first, to establish a marshland or perched water table above the tailings, one must define the hydrology of the site to define the water table and the groundwater fluctuations; and second, to determine the hydraulic conductivity and gas permeability of the tailings. In these project trials, coarse tailings resulted in high water/gas permeabilities and a perched water table could not be maintained without continuous irrigation.

Project: 2.21.1: Engineered Dry Covers for Tailings
Expenditures:$216 000

The objective was to develop laboratory and computer methodologies for testing, designing, placing and evaluating the effectiveness of engineered soil covers for reactive sulphide wastes. Practical concepts were proposed for designing high performance soil covers using locally available natural materials. Critical material properties required for design and prediction of performance were identified and these were obtained using specially designed laboratory columns. A computer model describing oxygen diffusion in soil covers was also developed and is currently being used in the demonstration column work for different cover projects (e.g. large scale tests at Waite Amulet (2.21.2) and Heath Steele (2.31.1)). These evaluation techniques and standardized laboratory procedures will permit the testing of candidate soils from which the full-scale results can be modelled and predicted.

Project 2.22.1: Assessment of Hardpan
Expenditures:$100,500

The project was designed to characterize the mineralogy of hardpan and to assess if it can be stabilized and used as an oxygen barrier. Petrographic studies and permeability tests were conducted on selected hardpan samples from four Manitoba

tailings sites. The general properties of hardpan were found to be initially encouraging as a relatively impervious and resistant zone was observed. Weathering and seasonal frost, however, tend to break down the hardpan, resulting in a fractured, softened zone which possesses only moderate resistance to infiltration and continuous oxidation. As a result, serious doubts remain concerning the use of hardpan to control the acid generation process. Also, no suitable method of artificially creating hardpan was determined and the project was terminated.

Project 2.23.1 Documentation of Disposal Methods for Tailings and Waste Rock (Draft Acid Rock Drainage Technical Guide)
Expenditures:$75,000

A comprehensive manual was prepared which provides an introduction to acid rock drainage (ARD) and direction on how best to deal with the problem. Techniques are discussed with respect to the handling of waste rock, tailings, open pits and underground workings. Current approaches in other parts of Canada and the world are also described. The manual has been prepared as a "how to" document and is being distributed in loose leaf binder format so that the manual can be easily updated in the future. The BC AMD Task Force recommended that the monitoring section (Chapter 11) of the Technical Guide be upgraded to incorporate recent developments in monitoring techniques, sampling equipment, data manipulation and statistical treatment (4.5.3)

Project 2.24.1: Vegetation Manual "Manual of Methods used in the Revegetation of Reactive Sulphide Tailings Basins"
Expenditures:$33,500

The manual provides a comprehensive description of procedures for preparation, neutralization, seeding and follow-up maintenance, if required, for revegetation of reactive sulphide tailings disposal areas in Canada. It describes and illustrates some of the more common agricultural equipment and fundamental, basic techniques required to prepare, seed and maintain mine waste areas revegetated. Case histories are appended that outline reclamation programs carried out at several Canadian mines including Falconbridge, INCO and Noranda.

Project 2.31.1a: Dry Covers on Waste Rock - Heath Steele
Expenditures:$312,000

Acidic drainage generation in waste rock poses a much different problem from that of tailings because of the huge difference in the size of the waste materials. Waste rock piles contain large voids which allow water and air to freely penetrate the pile and these conditions promote accelerated bacterial and chemical reactions. The objective of the project was to evaluate the effectiveness of engineered natural covers for reactive sulphide waste rock at the Heath Steele mine site. Locally available cover materials were sampled and characterized according to standard soil

properties. A column apparatus was used to measure the rate of oxygen diffusion through potential cover materials (2.21.1). Based on the results of the laboratory testing a practical, composite cover was designed using native materials. In order to confirm the effectiveness of the proposed cover it was recommended that the cover be field tested (2.31.1b).

TREATMENT

Project 3.12.1: Assessment of Natural Wetlands Affected by Low pH / Metal Contaminated Seeps
Expenditures:$40,000

The study examined natural wetlands near six base metal mines in Eastern Canada for evidence of biological mitigation of acidic drainage. Potentially suitable wetlands were identified and a field program was conducted to describe and compare these sites in terms of water and sediment chemistry, hydrology, and vegetation. The project was started too late to conduct a summer campaign; only fall results were obtained. There were large differences between the wetlands in metal loadings, groundwater inputs, water retention times, metal concentrations in wetland sediments, and vegetation communities. None of the sites, however, appeared to significantly reduce downstream loadings of metals or acidity levels during the fall. Prolonged drought at one site, severely reduced flows had prevented the calculation of influent and effluent metal loadings. The apparent lack of biologically-related improvement of AMD was most likely a consequence of (1) low temperatures, ca. 4°C, (2) channelized flow patterns within the wetlands, and (3) limited contact of acidic drainage with anoxic sediments. Inputs of other seeps and groundwaters to the wetlands were significant complicating factors, especially at the Kam-Kotia site. High metal concentrations in wetland sediments indicated that the wetlands had removed metals in the recent past.

Project 3.21.1a: Metals Recovery from Acid Mine Drainage - Phase A
Expenditures:$25,000

A background survey and a review of technology were completed on methods which could remove metals such as Cu, Ni, Zn from acidic drainage and reduce the potential toxicity of treatment sludges. A summary report was completed in November 1991. Three technologies were determined to have economic and technical potential. They were; copper cementation, ion exchange, and selective precipitation. Since cementation is a well defined and frequently used method, ion exchange and selective precipitation of metals were methods recommended to be followed in further research. These research projects were put in place in 1992. It was indicated that a cross-Canada survey of acid drainage water quality was

needed.

MONITORING

Project 4.1.1: Field Methods Manual - Tailings
Expenditures:$29,000

Accurate monitoring of a tailings impoundment requires that the samples collected for physical, chemical and microbiological analyses be of high quality. A manual of sampling methodologies applicable to tailings impoundments and involving the collection of representative solid, liquid and pore-gas samples was prepared. It offers guidance and recommendations on the selection of methods, emphasizing minimal sample disturbance and contamination. For each method, the objectives, descriptions, advantages and disadvantages are presented. Flowcharts are presented to summarize the methods and guide in their selection. A summary of quality control recommendations defined in the three primary chapters is also presented.

Project 4.3.1: Standard Reference Materials - Tailings
Expenditures:$50,000

The key to reliable and reproducible analytical results is the availability of good, relevant standard reference materials. CANMET has an established Canadian Certified Reference Materials Program (CCRMP) through which four mill tailings materials were selected, prepared and certified. The four samples were prepared as composite reference materials from pyrite/pyrrhotite tailings from INCO, Falconbridge and Noranda. Analyses of nineteen major and minor elements were performed by seventeen laboratories on six replicates for each of the four standard materials. The reference materials, RTS-1, RTS-2, RTS-3, and RTS-4, are currently available through CANMET with all applicable supporting documentation.

Project 4.7.1: Optimum Sampling Frequency
Expenditures:$27,000

The project objective was to determine optimum water quality sampling frequencies and most representative, measurable parameters (eg. pH, conductivity) for AMD effluent by evaluating four of the most extensive water quality data sets associated with acid mine drainage in British Columbia. A number of potential

failings were discussed, including: fixed-frequency single samples used in mean loading estimates; inaccurate or incomplete flow estimates; significant short-term events; and the overemphasis of analytical accuracy versus timely, representative sampling. It is recommended that acid mine drainage monitoring schedules be revised to consider the information needed for management; ie., accuracy, lag times, risks, and parameter variation (spacial and temporal). As well, pre-operational studies at proposed mine sites should include measures of natural variation and should span seasons of anticipated high acid mine drainage discharge to obtain adequate baseline data.

Project 4.7.2: Biological Monitoring of Acid Mine Drainage
Expenditures:$21,000

The objectives were to determine the most effective methods for biological monitoring of acid mine drainage through a review of existing methods and assess and recommend the most effective techniques. A variety of indicators are suitable for detecting impacts of AMD, but few have been linked to chronic whole organism responses. The most promising and proven biological monitoring techniques, however, include: benthic community responses; growth and reproductive parameters of fish populations; survival in a designated zone of impact; and other changes at the individual, biochemical level. It was determined that no single approach to the problem of biological effects monitoring will completely satisfy present needs. the most cost-effective approach to assessing ecosystem health in waters affected by AMD was found to involve a multi-disciplinary, "top-down" approach, which relies on the detection of impacts before they become irreversible.

Project 4.7.4: Acid Mine Drainage Sediment Monitoring
Expenditures:$6,500

This project was designed to review all available literature pertaining to sediment monitoring techniques and to recommend the relevance and applicability of these techniques for measuring the impact of AMD. The review focuses on assessment of sediment quality through sediment chemistry, bioassay testing and benthic macroinvertebrate community structure. Analytical methods for sediment chemistry are reviewed and summarized. Sampling devices, design, handling and preparation are evaluated with respect to sediment toxicity testing. Freshwater sediment

bioassays with bacteria, algae, invertebrates and fish are reviewed. Guidelines for sediment chemistry, bioassay testing and benthic macroinvertebrate community assessment are provided, while stressing proper QA/QC. The application of the Sediment Quality Triad approach is recommended, developed to utilized three measures of sediment quality: sediment chemistry, which measures contamination; sediment bioassay, which measures toxicity; and biological community structures, which measures biological alteration.

TECHNOLOGY TRANSFER

Project 5.5.1: Preliminary MEND Research Plan
Expenditures:$25,000

The original plan (RATS) was produced in 1988. This plan called for an expenditure of $12.5 million over 5 years. In May 1991, the MEND Management committee requested that each of the technical committees produce a revised plan for MEND. The technical committees reviewed the progress to date; examined the priorities; produced a focused plan with distinct outputs; and defined an end to the program. The Revised Research Plan for MEND includes the decisions of the MEND Board of Directors to expand the program to $18 million total expenditure and that the program end in December 1997.

APPENDIX C

Recently Completed Projects

March 1993

Number	Titles:
1.41.1	International Workshop on Waste Rock Modelling
2.11.1c	Evaluation of Existing Underwater Disposal Sites
2.11.1d	Peer Review on the Subaqueous Disposal of Tailings
2.23.2a	Hydrogeological and Geochemical Analysis of the Thickened Tailings Disposal (TTD) System at Kidd Creek Mines
2.32.1	Blending and Segregation of Waste Rock - Kutcho Creek
2.32.2a	Co-Disposal of Tailings and Waste Rock in Cells at Les Mines Selbaie
2.33.1	ARD Remediation Measures at Four Norwegian Mines
2.41.1a	Electrochemical Oxidation/Passivation of Sulphides
2.44.1	Microbial Plugging of Mine Tailings to Reduce the Production of AMD
3.11.1a-c	Treatment of Acidic Seeps Using Wetland Ecology and Microbiology
4.5.2	Field Sampling QA/QC
4.7.3	Aquatic Invertebrate Monitoring
4.7.5	Ion Speciation
4.7.6	Paleolimnology Techniques
5.4.1	Acid Rock Drainage Technical Guide - version française
5.6.1	Second International Conference on the Abatement of Acidic Drainage

COMPLETEDPREDICTION - **Modelling**
March 1993

Project 1.41.1: International Waste Rock Modelling Workshop
Budget: $10,000
Sponsors: British Columbia, CANMET, Québec, DIAND, Falconbridge, HBM&S, INCO, Noranda, Ontario, Teck
Expenditures: $7,770
Contractor: In-House, MEND Secretariat

Objective:

The purpose of the workshop was to focus research and development of modelling capabilities for waste rock dumps to the needs and requirements of users by identifying: current modelling capabilities; requirements of the industry and regulatory groups; gaps in current capabilities to address these requirements; and available (international) expertise in these areas.

Outputs:

An international workshop on modelling the generation and transport of acid rock drainage from mining waste rock was hosted by MEND. The three-day workshop was held in Toronto at the end of September, 1992. All five participating countries (Australia, Canada, Norway, Sweden, United States) have indicated a willingness to work towards developing the capacity to model acidic drainage from waste rock. This willingness is based on a need to be able to predict, in the long term, the contaminant flux and therefore liability associated with (potentially) acid-producing dumps and the mitigating effects of various control measures. A recommended international approach to the development of waste rock modelling capabilities was drafted. The workshop proceedings, generated through the MEND secretariat, will be made available as a MEND report in early 1993.

Recommendations:

Based on the workshop it is suggested that a useable model should incorporate the following: oxygen and heat transport; solute movement and hydrology; and geochemistry. The ability to model oxygen and heat transport within a waste rock dump is, for the most part, possible. Advances in parameter prediction for new mines based on available data is however recommended. The area of solute transport and hydrology under mainly unsaturated conditions is less advanced. The

parameters must be priorized to ensure that the most significant are addressed Despite the complex nature of the system, simulation of the processes is considered do-able within the time and budget allocated in the Revised Research Plan. The geochemical processes are considered the most difficult to simulate effectively, and in some cases may not be possible. Among other actions, a critical review of the key processes and current modelling capabilities is recommended to assess potential for incorporation (1.42.1) into the overall predictive capacity.

COMPLETEDP&C - Underwater Disposal
March 1993

Project 2.11.1c: Evaluation of Existing Underwater Disposal Sites
Budget: $50,000
Sponsor: Placer Dome
$67,625
Expenditures: $67,625
Contractor: Rescan Environmental Services Ltd.

Objectives:

It is believed that the covering of waste rock and tailings sites with water will minimize the transport of oxygen and therefore limit or even totally prevent acid generation. The objectives of this project are to establish the validity of this belief by evaluating representative existing sites, to examine the impacts which result when in-lake disposal systems are used, and to recommend criteria for the safe underwater disposal of tailings.

Outputs:

In 1989, a work plan was developed which consisted of evaluating each of four lakes over a two year period. A preliminary evaluation and geochemical assessment on the interstitial water was completed (Project 2.11.1a and 2.11.1b) on three of the four lakes. This work concludes the preliminary assessment of Benson Lake (Project 2.11.1a).

The project focused on the chemical and biological aspects of changes in Benson Lake following subaqueous tailings disposal. Keogh Lake which is located about 12 km to the northwest of Benson Lake was used as a control for water chemistry, sediments, and biota. The latter was chosen as a pristine, hydrographically similar "control basin" in order to permit geochemical comparison between lakes with tailings and without tailings.

Two reports were produced from the Benson Lake study. The first is titled "A Preliminary Biological and Geological Assessment of Subaqueous Tailings Disposal" and is available from CANMET and the second "Chemical Diagenesis of Submerged Mine Tailings in Benson Lake and Natural Sediments in Keogh Lake" will be available in 1993.

Recommendation:

At the request of the MEND Board of Directors, a scientific and technical review of all aspects of the work conducted to date was completed (Project 2.11.1d). The future direction of the subaqueous tailings disposal program will be based on the results of the peer review.

COMPLETEDP&C - Underwater Disposal
March 1993

Project 2.11.1d: Peer Review on the Subaqueous Disposal of Tailings
Budget: $45,000
Sponsors: Placer Dome
$ 2,000
CANMET $32,350
Expenditures: $34,350
Contractor: The Rawson Academy of Aquatic Science

Objectives:

The review had two objectives. In summary, these were to:

- provide technical and scientific assessment of MEND studies on subaqueous disposal of tailings; and
- outline additional requirements necessary for the MEND studies to maintain a credible scientific approach.

Outputs:

The Peer Review was carried out by The Rawson Academy of Aquatic Science (RAAS) with the aid of highly qualified and experienced scientists, each a specialist in one or more fields of science dealing with aquatic ecosystems (e.g. sediment/water interactions, limnology, community structure and biological response to stress, and remedial actions technology).

The reviewers agreed that the work carried out to date on the three lakes reviewed, Mandy, Anderson and Buttle (Benson was not complete) was well done. Other areas of research that the reviewers thought should have been done, were not in the original scope of work. It was also noted that the lake studies were completed with limited funds.

The report identified key areas that are lacking in information. For instance, the studies of background limnologies for the lakes were not suitable to present to regulatory personnel, the seasonal and yearly changes that occur in the water column loadings would have to be addressed and the field experiment for metal flux measurements, although well done, do not assess the quantitative fluxes which are considered important. Some additional literature reviews (e.g. metal toxicology) and a complete program for documenting QA/QC were suggested and the definition of the types of additional field data (e.g. geochemical) and methods for data collection were presented in the report.

Recommendation:

The original concepts of significantly reduced reactivity of these sulphide wastes have been verified by sophisticated geochemistry work and underwater disposal appears to have high potential to prevent acid mine drainage. Additional work is needed and this work will start early in 1993 to develop a more complete understanding of the sites under study.

COMPLETEDP&C - **Others**
March 1993

Project 2.23.2a: Hydrogeological and Geochemical Analysis of the Thickened Tailings Disposal (TTD) System at Kidd Creek Mines.
Budget: $60,000
Sponsor: ..... Falconbridge
$67,000
Expenditures: $67,000
Contractor: Noranda Technology Centre

Objectives:

The objectives of this study was to measure the hydraulic properties of the TTD tailings system to obtain a verification of the high moisture retention characteristics of the disposal technique.

Outputs:

The Robinsky TTD system used at Kidd Creek has the potential to reduce acid generation and seepage by creating a homogeneous tailings mass of low hydraulic conductivity and high moisture retention characteristics in which oxygen entry and the resulting tailings oxidation are limited.

Noranda Technology Centre carried out a field evaluation of the site hydrology to obtain a verification of the high moisture retention of the TTD deposit. Data from these measurements were combined with other Kidd data to develop a hydrologic budget for the tailings. Analysis of porewater quality in the unsaturated and saturated zones of the tailings was also conducted.

The result of the study inferred the presence of a significant capillary fringe, or tension-saturated zone above the water table, from measured physical characteristics such as tailings grain size and porosity.

Analysis of porewater in the unsaturated and saturated zones indicated that sulphide oxidation is occuring within the tailings mass. However, if tailings disposal were to cease, the release of contaminants from the tailings to the environment should remain at present rates because porewater velocities are low and because of the sustained presence of near-surface saturated conditions.

Recommendation:

The study suggested that the TTD method seems to be advantageous because of the

low dissolved metal fluxes to the environment. Work recommended by the contractor included additional hydrologic budget component measurement and modelling, water quality sampling and analyses, and hydrologic experiments under controlled laboratory conditions. This is the first year of a two-year study and it is recommended that approval be given to the second year of the study (Project 2.23.2b).

COMPLETEDP&C - Waste Rock
March 1993

Project 2.32.1: Blending and Segregation of Waste Rock - Kutcho Creek
Budget: $140,000
Sponsors: Sumac Mines
$110,000
British Columbia ..... $ 15,000
CANMET ..... $ 15,000
Expenditures: $140,000
Contractor: Rescan Environmental Services Ltd.

Objective:

The objective was to evaluate, through laboratory and field analysis, the effectiveness of segregating and blending acid-generating waste rock and alkaline material as a method of preventing or controlling AMD.

Outputs:

In the first year, acid-base accounting test results confirmed that footwall rocks are potentially acid-generating and that hanging wall rocks have the potential to neutralize acid. Laboratory humidity cell tests composed of blended ratios of waste rock material demonstrated that the rate of acid generation was significantly reduced. For the blended test cells the rate of neutralization, at least over the short term, was sufficient to maintain a slightly alkaline pH in the leachate.

The field work consisted of three large scale weathering tests (20 tonne waste rock pads) to simulate blending under natural weathering conditions. Results from the test pads are not as conclusive as the laboratory results. It was discovered that leachate quality was dependent upon flushing rates as opposed to the actual acid generation rate. During the second year of a four year monitoring program, it was observed that leachate from two of the pads was consistently neutral in pH. The third was acidic. This was attributed to a reduction in flushing of the waste rock and acid products accumulated due to a soil cover, resulting in a lower pH. In other words, the low pH did not necessarily reflect increased acid generation rates.

Long-term predictions have been made based on the results from the humidity cell test work. They show that the neutralizing potential could be consumed in as early as 100 weeks with acidic conditions continuing until all sulphides were oxidized. Based on these predictions, blending of Kutcho waste rock, even at 1:1, would not be a viable option. A separate analysis has determined that the costs associated

with blending large amounts of waste materials in a full scale waste dump would be excessive. The report will be available from CANMET in 1993.

Recommendation:

No follow-up work is recommended at this time.

COMPLETEDP&C - Waste Rock
March 1993

Project 2.32.2a:	Co-Disposal of Tailings and Waste Rock in Cells - Les Mines Selbaie
Budget:	$ 96,000
Sponsors:	..... CANMET $20,000
	Québec..... $76,000
Expenditures:	$ 96,000
Contractors:	Les Mines Selbaie/CANMET
	Golder Associates

Objective:

The objective of the project was to evaluate the concept of co-disposing reactive sulphide waste rock with non-reactive tailings in basins in order to minimize acidic drainage from the waste rock.

Outputs:

The co-disposal concept involves the construction of a basin, the placement of highly reactive waste rock in the bottom of the basin, and infilling above with alternate layers of less reactive waste rock and non-reactive tailings. A final layer of non-reactive tailings completes waste placement. The design seeks to create saturated conditions in the reactive waste and minimize groundwater flow in the basin.

Phase (a) consisted of field reconnaissance, characterization of both tailings and waste rock and potential basin construction materials, and a preliminary geotechnical design of the basin. A final evaluation report will be available from CANMET in 1993.

The prediction tests carried out on the tailings materials indicated that the tailings are acid producers. According to Les Mines Selbaie they have two types of tailings, one contains less sulphur than the other. Further prediction tests on both types of tailings have confirmed that the tailings are likely to generate acid.

Recommendation:

The project was based on the concept of co-disposing acid-generating waste rock with neutral tailings in a basin and to evaluate this disposal option. Since the

tailings are acid producers, no follow-up work is recommended.

Co-disposal of reactive sulphide wastes with non-reactive (or desulphurized) tailings has been identified in the Revised Research Plan as a Priority II program area. The committee is still willing to consider projects in this area.

COMPLETEDP&C - Waste Rock
March 1993

Project 2.33.1 ARD Remediation Measures at Four Norwegian Mines
Budget: $38,500
Sponsors: British Columbia $19,245
Norwegian Pollution Control $19,245
Expenditures: $38,500
Contractor: Steffen, Robertson & Kirsten

Objective:

The purpose of this project was to provide a transfer of recent Norwegian experiences and technology on the remediation of acidic rock drainage (ARD) at four sulphide mines in Norway to Canada. Results from full-scale projects are currently not available in Canada.

Outputs:

The project was undertaken to provide information of full-scale remediation measures taken in Norway. The study addresses operational difficulties, procedures, results and costs of natural sulphate reduction, geomembrane covers and underwater disposal.

A report titled "ARD Remediation Measures at Four Norwegian Mines" has been produced. The report makes conclusions and recommendations about the remediation methods used at the four sites:

- Lokken mine plans to divert rock pile seepage underground where natural sulphate reduction is occurring;
- waste dumps at Kjoli mine were consolidated and covered with a 2 mm HDPE synthetic membrane to control infiltration;
- Killingdal mine is treating rock pile seepage by diverting it underground and utilizing the natural convection through the mine as an evaporative treatment process; and
- waste rock at Skorovas mine has been deposited in a nearby lake under a permanent water cover of 2 metres.

Recommendations:

The final report will be evaluated by members of the Prevention and Control

committee prior to publication as a MEND report.

No follow-up work is recommended at this time.

COMPLETEDP&C - **Others**
March 1993

Project 2.41.1a: Electrochemical Oxidation/Passivation of Sulphides
Budget: $60,000
Sponsors: Noranda Technology Centre $ 5,000
Lac Minerals $10,000
HBM&S $10,000
CANMET $35,000
Expenditures: $60,000
Contractor: CANMET

Objective:

The objective of this project was to develop electrochemical methods for the prevention of atmospheric oxidation, acid generation and leaching of sulphide tailings.

Outputs:

In this project, it was established that a passive iron oxide film grown on pyrite/pyrrhotite can protect the substrate from oxidation on exposure to air and hence prevent acid generation. It was also shown that a bed of pyrrhotite rich tailings can be converted into a hardpan by a cathodic treatment followed by exposure to air under moist conditions. Six weeks after switching the current off, the bed automatically consolidated into a hardpan with some expansion. The solution percolating through this bed in the earlier stage of hardening had a pH of 5.5 and the iron concentration was lowered to natural equilibrium values.

At a progress review meeting in November 1991, it was felt that several experimental verifications were necessary before further work could be undertaken. A proposal, identifying the work requested to complete 2.41.1a and cost, was prepared by CANMET and submitted to MEND. After a review of this proposal it was recommended that the project not continue to larger scale tests.

A final report and an addendum to the final report titled "Electrochemical Methods for the Prevention of the Oxidation of Sulphide Tailings and the Resultant Acid Generation" will be made available in 1993.

Recommendations:

The concept of in situ formation of synthetic hardpan by surface chemical treatment, briefly presented in Phase a, is being followed by CANMET. Following a meeting with the Project Leader, it was agreed that a proposal would be submitted to the New Ideas Task Force for consideration.

COMPLETEDP&C - **Others**
March 1993

Project 2.44.1: Microbial Plugging of Mine Tailings to Reduce the Production of Acid Mine Drainage (AMD)

Budget: $100,000

Sponsors: Noranda Technology Centre $20,000

Teck	$10,000
INCO	$10,000
CANMET	$60,000

Expenditures: $100,000

Contractors: C.A.R.E. International Inc.
CANMET

Objective:

The objective of the project was to evaluate, at a laboratory scale, the microbial plugging technology as a method of reducing the production of AMD.

Status:

The project involved the use of starved indigenous microorganisms called ultramicrobacteria's (UMB) which, when exposed to nutrients, reproduce and excrete polymers. The polymers fill the void spaces in the tailings, effectively creating a microbial plug.

The laboratory test results obtained in 1991, showed that an oxygen scavenging layer could be established. This, however, did not reduce the permeability of the tailings as expected. At a progress review meeting in November 1991, the discussion centred on the required deliverables, particularly relative to permeability and demonstrated plugging. A new proposal addressing the concerns of the committee was submitted by CANMET in 1992 with the objective of determining if a microbial cap capable of reducing both the penetration of oxygen and water could be formed.

The conclusions of the study were that: it was not demonstrated that a microbial cap could significantly reduce the permeability of the tailings over long periods of time; a decrease of the oxygen penetration was observed for the columns that received nutrients; an increase in pH was observed for all of the permeates from the columns that received nutrients; and addition of UMB's to the tailings was not necessary because native strains were present in the tailings. It was also noted that although a reduction in permeability was not observed in the experiments, it is

possible that in fine textural tailings, a significant reduction in water permeability would be expected. The report will be available from CANMET in 1993.

Recommendation:

No follow-up work is recommended at this time.

COMPLETED **TREATMENT**

March 1993

Project 3.11.1: Treatment of Acidic Seepages Employing Wetland Ecology and Microbiology - Phases A, B and C

Budget: $608,000

Sponsors:

CANMET $157,000

INCO $274,000

Environment Canada $147,000

Québec $ 30,000

Denison $ 71,000

Expenditures: $679,000

Contractor: Boojum Research Limited

Objectives:

This project was designed to investigate the use of microbiology and ecology of wetlands to reduce acid mine drainage. A major objective was to develop design parameters for the Acid Reduction Using Microbiology or the ARUM process. The project was composed of the following phases:

3.11.1a Conduct microbiological nutrient requirements and cellulose degradation studies in the laboratory, set up field systems at Elliot Lake and Copper Cliff.

3.11.1b Microbiological and water quality monitoring. Conduct process capability tests.

3.11.1c Monitor system performance and make final adjustments, (1991 season).

3.11.1d Monitor (1992) and establish performance criteria for operating systems.

Outputs:

Phase A and B were completed in 1990, and C in 1991. Flow-through control, the relationships between amendment quantity, flow rates and seepage characteristics were tested. Organic carbon nutrient was partially supplied by floating cattail mats, a significant innovation of the system. Reports were received but not distributed.

The key results related to water quality; significant alkalinity was created (27 kg/tonne of water) and the heavy metals are precipitated as sulphides. However, the system appeared to be capable of handling only low flows, less than 3 to 5 litres/minute. At the very low flow of 1 litre/minute, very good water quality had

been produced (1 litre/minute is equivalent to 4 months retention time).

Recommendations:

The Treatment committee carefully reviewed the results achieved to the end of 1991 and recommended that the final year's monitoring and determination of performance criteria be completed (3.11.1d).

COMPLETED **MONITORING**
March 1993

Project 4.5.2: Field Sampling Quality Assurance/Quality Control (QA/QC)
Budget: $9,500
Sponsor: .....Noranda
$9,500
Expenditures: $9,500
Contractor: Norecol

Objective:

To carry out a literature review on field sampling criteria with particular emphasis on quality assurance and quality control protocols. The focus is on components of programs for predicting or detecting acid mine drainage and its environmental effects.

Outputs:

A QA/QC program begins with setting a data quality objective, which defines the level of uncertainty that a decision maker is willing to accept in decisions made with environmental data. The quality assurance component of the program is the set of operating principles that, if strictly followed, should produce results which meet the data quality objective. The quality control component of the program is the assessment, through measurements of precision, accuracy, and representativity, of whether the data quality objective has been achieved.

Common elements of QA/QC programs for field studies include selection of the sampling locations, definition of the required number of replicate samples, and choice of the appropriate sampling device to achieve precision, accuracy, and representativity of the data. Other common elements include maintenance of field notes, technician training and evaluation, and standardization of sample collection, preservation and storage protocols.

This document reviews the elements of field QA/QC programs for sampling surface and groundwater, effluents, sediments, soils, tailings and waste rock for chemical parameters related to AMD. It also reviews QA/QC programs for: stream flow measurements and biological effects monitoring, including sampling populations of fish, benthic invertebrates, periphyton, zooplankton, and phytoplankton; metals in fish tissue; and the presence of *Thiobacillus ferrooxidans*.

Recommendations:

In monitoring and predicting impacts of acid mine drainage, the elements of QA/QC programs for laboratory analyses are reasonably well defined. More emphasis needs to be placed on the implementation of QA/QC protocols for field programs.

COMPLETED **MONITORING**

March 1993

Project 4.7.3: Aquatic Invertebrate Monitoring

Budget: $136,000 Total: 1989/90 ($53k), 1990/91 ($68.5k), 1991/92 (14.5k)

Sponsors: British Columbia $75,000

CANMET	$42,000
Environment Canada	$ 4,567
Noranda	$14,563

Expenditures: $136,130

Contractor: Limnoteck Research and Development Inc.

Objectives:

This three year research project was aimed at evaluating a trough apparatus for measuring the environmental effects of acid mine drainage on aquatic invertebrates.

Outputs:

1989/90: The objective of the first year was to construct a flow-through trough apparatus and to test it with preselected concentration of treated acid mine drainage. The study was designed to remove uncertainty in the assignment of allowable dilution rates of treated acid mine drainage that are discharged into Foxy Creek near the Equity Silver Mine operations in British Columbia. The apparatus was observed to be a powerful tool capable of accurately determining ecosystem response curves for effluent discharges as indicated in the report titled "The Effect of treated AMD on Stream Macroinvertebrates and Periphytic Algae: An in situ Mesocosm Experiment".

1990/92: Work involved monitoring chemical variation and changes in abundance and community structure of benthic insects and periphyton in a stream mesocosm that was dosed with a gradient of raw acid mine drainage dilutions from Equity Silver. The report, "Stream Community Responses to a Gradient of Acid Mine Drainage Additions", concludes that at dilutions of less than 1:1,000 there is clear evidence that the acid neutralizing capacity of the stream was exceeded. Responses at varying dilutions indicated that a metal concentration in solution which causes a change in community structure may be lower when that metal is part of a complex solution of metals. Models of indices of benthic response to the gradient of AMD additions were generated and compared to the CCREM guidelines .

Recommendations:

Together with descriptions of changes in chemical dynamics at each of the AMD treatments, the approach outlined using the trough apparatus was considered to be comprehensive and to provide more relevant information on community processes than could be collected through laboratory bioassay or monitoring studies.

COMPLETED **MONITORING**

March 1993

Project 4.7.5: Ion Speciation
Budget: $35,092
Sponsor: British Columbia
$ 6,000
CANMET ..... $ 5,500
Noranda $23,592
Expenditures: $35,092
Contractor: CB Research International

Objective:

The project objective was to provide estimates of the most probable species of a given metal, and their redistribution due to changes in water chemistry as a result of anthropogenic inputs. Specific objectives included: determination of metal complexes with natural organic matter; determination of the metal complexing capacity of a selected receiving water and conditional stability constants of significant metal complexes; and use of the model for calculating ion species upon mixing raw AMD with the receiving water for the evaluation of toxicity.

Outputs:

Ionic speciation must be considered in the development of monitoring criteria and monitoring programs which attempt to predict the environmental impact of metals introduced into the environment. Toxicity of dissolved metals is dependant on the physical/chemical parameters associated with specific species.

The model, described in the report titled "Evaluation of *B.C. Mine* for Application to Acid Mine Drainage Regulations", gives projections of metal speciation at any one point in time from a given location. Historical data on the site combined with total metal levels provide the basis for potentially using predictive modelling as part of the regulatory process.

Recommendations:

With the information provided, in terms of organic binding and free metal ion activity, it may be possible to provide increased metal into the system before biological impact is observed. In addition to this, metal metabolism of indicator organisms as a controlling system may well be an important consideration. At this

time, further development of the model *B.C. Mine* is not being pursued.

COMPLETED **MONITORING**

March 1993

Project 4.7.6: Paleolimnology Techniques
Budget: $16,500
Sponsor: .....Noranda
$16,500
Expenditures: $16,500
Contractor: Norecol

Objective:

Through review of the literature, the possibilities were evaluated for using paleolimnology techniques to establish pre-mining baseline levels of biological communities at currently active or closed sites where such information was not collected.

Outputs:

The extent of an operation's environmental impact can only be determined with respect to original, baseline values. Biological communities are very sensitive to environmental stress such as results from acidic drainage, and are also extremely variable. Long term studies may be necessary to establish baseline levels at existing mine sites, however cost is often a prohibiting factor. The use of paleolimnology was considered for describing past conditions including, for example, pre-mining conditions.

Large scale studies in North America and Europe have successfully used paleolimnological indicators for effects of acid rain and these have been reviewed to evaluate whether similar techniques could be applied to AMD monitoring. The report concludes that it should be possible but that it would first be necessary to develop a calibration data set which relates species assemblages of the chosen taxon to levels of AMD-related parameters. Diatoms were the recommended indicator taxon.

Recommendations:

The report recommends a methodology for carrying out a preliminary calibration study on diatom distribution in lake sediments with water chemistry. Currently there is no commitment to develop an appropriate calibration data set.

COMPLETEDTECHNOLOGY **TRANSFER**

March 1993

Project 5.4.1: Acid Rock Drainage Technical Guide - version française
Budget: $23,700
Sponsor: .....Québec
$23,700
Expenditures: $23,700
Contractor: École Polytechnique

Objective:

Provide version française of Draft Acid Rock Drainage Technical Guide and present seminars to the mining industry.

Outputs:

The Guide provides the most comprehensive and easy-to-understand overview of the issue and technical aspects of acidic drainage (2.23.1). Increase in understanding of the issue, particularly in the mining industry, is a MEND priority.

One hundred copies of the french version of Draft Acid Rock Drainage Guide were printed and seminars were held in Val d'Or and Noranda to inform the industry of the existence of the guide.

Recommendation:

No follow-up work is recommended .

COMPLETEDTECHNOLOGY **TRANSFER**
March 1993

Project 5.6.1: Second International Conference on the Abatement of Acidic Drainage

Budget: $127,000

Sponsors: CANMET($30k), Teck($8k), INCO($11k), Noranda($20k), Environment Canada($15k), Cominco ($5k), Rio Algom ($4k), Falconbridge ($4k), Placer Dome ($4k), Cambior ($4k), MITEC ($7k), HBM&S ($3k), Ontario ($7), B.C. ($3k), MAC ($2k), Québec ($10k)

Expenditures: $127,000

Objective:

Plan and host an International Conference on the Abatement of Acidic Drainage.

Outputs:

The Conference was an outstanding success. Over 500 delegates from around the world attended the 3 day conference at the Sheraton Hotel in Montreal on September 16, 17 and 18, 1991.

There were 134 technical papers presented in 15 different sessions. Also there were 3 days of poster sessions. Workshops were presented on September 14 and 15 and these workshops were well attended. There were field trips after the conference, to Bathurst, New Brunswick, to Noranda, Québec and to Elliot Lake, Ontario.

MEND participants took the opportunity to present and listen to many of the excellent presentations, to meet many people from Canada and around the world, and to have several MEND technical committee meetings and to invite interested guests to these meetings. Many attendees commented that the conference was the best conference of any kind that they had ever attended. The proceedings (4 volumes) are available from CANMET.

Recommendation:

Participation in the Third International Conference on Abatement of Acidic Drainage, Pittsburgh, 1994 will be a good opportunity to exchange new

information with those working on acidic drainage research.

APPENDIX D

Active Projects **March 1993**

Number	Titles:
1.12.1	Compile AMD Prediction Data
1.14.2	Monitoring & Modelling AMD from Waste Rock: Mine Doyon Phase II
1.19.1	Kinetic Test for Cinola Gold Project
1.21.1d	ß-Evaluation of Tailings Model
1.22.1	ANSTO Model at Health Steele
1.23.1	Compilation of Rules for Prediction of AMD
1.25.1a	The Development of a Soil Atmosphere Flux Model for the Design of Sulphide Tailings Cover Systems - Phase I
1.26.1	Development of a Modelling Methodology for Prediction of Seepage Quality from Acid-Generating Waste Rock - Phase I
1.31.1	Fundamental Reaction Kinetics Study of Weathering Employing SIMS
1.32.1	Prediction and Prevention of Acid Rock Drainage - A Geological and Mineralogical Approach
2.13.1	Flooding of Existing Tailings Sites - Quirke Lake
2.13.2	Flooding of Existing Sites - Solbec Cupra
2.21.2	Engineered Dry Covers for Tailings - Noranda
2.22.2	Evaluation of Dry Covers Built From Mine Tailings
2.23.3	Porous Envelope Surround Disposal Method - Falconbridge
2.25.1	Reclamation of Tailings Using Municipal Solid Waste Compost
2.31.1b	Dry Covers on Waste Rock - Heath Steele
2.35.2a,b	Lysimeter Evaluations of Cover Alternatives - Noranda
2.42.1a	Development of Synthetic Polymers - Laurentian
3.11.1d	Treatment of Acidic Seeps Employing Wetland Microbiology
3.12.2	Evaluation of Wetlands at Panel "A" Site
3.13.1a	Passive Treatment of Small Seeps
3.21.1b	Removal of Metals from AMD - Ion Exchange
3.21.2a	Removal of Metals from AMD - Chemical
3.31	Use of Lime Sludges for Capping
4.2.1	Decommissioning Criteria
4.5.1	Field Methods Manual - Waste Rock
4.5.3	ARD Technical Guide Revision - Monitoring Section
4.6.1	Assessment of Geophysical Monitoring Methods
4.6.2	Continuous Monitoring of AMD - Literature Review
4.8.1	Monitoring of the Solbec Cupra Pit

5.3.1 Laurentian Database

ACTIVE PREDICTION - Chemical Prediction
March 1993

Project 1.12.1: Compile AMD Prediction Data - DBARD
Budget: $45,000
Sponsors: British Columbia $32,300
CANMET $12,300
Expenditures: $24,600
Manager: W. Price, B.C. MEMPR
Contractor: Morwijk Enterprises/University of British Columbia

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Objective:

To improve the existing British Columbia acid mine drainage database by: developing an accessible, user-friendly database program; and adding available prediction data for new mine projects in B.C. since 1980. The data can then be analyzed for common trends and important differences, and recommendations can be made for improved approaches to pre-mine prediction.

Status:

The collection of waste rock and tailings prediction data (mine site characteristics, static and kinetic test data) has been done in house by both the B.C. Ministry of Energy, Mines and Petroleum Resources, and Environment Canada. A computer database has been developed through Morwijk Enterprises using dBase III plus, and date-entry templates prepared into which information can be entered. Contacts have been made in the United States and elsewhere for potential inclusion of international data into the system.

Demonstration discs of the input data templates, as well as a users manual are presently available. An alpha-version of the software is available and has been reviewed, and the comments received will be incorporated where applicable. Output capabilities have not yet been introduced.

Further development and maintenance of the database will be done through the University of British Columbia under the Chair for Mining and the Environment. This transfer will be facilitated by the original contractor though an initial briefing.

Priorities for the upcoming year include a reassessment of the software, and data entry system. It has been recommended that the database be made available through computer network systems, and alternative software options will therefore be

assessed. Data entry will follow and will initially be focused on sites in British Columbia.

ACTIVE PREDICTION - Modelling
March 1993

Project 1.14.2: Monitoring & Modelling AMD from Waste Rock: Mine Doyon Phase II
Budget: $450,000
Sponsors: .....Cambior $ 75,000
CANMET ..... $ 50,000
Québec.....$150,000
Lac Minerals ..... $ 75,000
Expenditures: $200,800
Manager: A. Paquet, CRM
Contractor: Laval University

Objectives:

- Continue the collection of baseline data; physical, chemical and bacteriological field measurements, chemical analyses, and meteorological data initiated in Phase I.
- Develop a waste rock alteration indicator for determining the extent of oxidation.
- Determine the rate of AMD generation and predict long-term behaviour as a function of potential control measures.

Status:

As recommended (1.11.1 & 1.24.1), Mine Doyon has afforded an excellent opportunity to study a waste rock dump in detail, and to advance predictive capabilities. Phase I (1.14.1) resulted in the instrumentation and detailed characterization of the south waste rock dump at La Mine Doyon, as well as a long-term prediction of acid generation potential using two independent methods. Phase II continues and has augmented the monitoring program initiated in Phase I. From the information collected, geochemical, physical and hydrologic simulation capabilities are being developed.

Geochemical modelling is concentrating on the comparison of ARD compositions along a typical flowpath from the dump surface through the unsaturated zone, saturated zone, and collection ditches. The dump is a major reservoir of acidity and the storage has been estimated in relation to annual discharge.

Physical modelling of heat transfer as related to diffusive transport is completed

and transient conditions involving air convection, water vapour transport and heat production is in progress.

Hydrologic modelling has concentrated in the analysis of storm hydrographs collected since the spring of 1992. A unit hydrograph has been derived for each sub-basin and techniques of hydrograph separation are being tested to evaluate the lag time of reaction between precipitation events and their manifestation in the hydrographs. Water balances in the dump will be established and average residence time along different paths from dump surface to drainage ditches will be estimated.

ACTIVE PREDICTION - Chemical Prediction
March, 1993

Project 1.19.1: Kinetic Test for Cinola Gold Project
Budget: $100,000 Total: 1990($43.7k), 1991($26.3k), 1992/93($30k)
Sponsors: British Columbia
$25,160
CANMET $20,000
City Resources..... $ 2,400
Environment Canada $46,800
Expenditures: $64,360 Total: 1990($38.06k), 1991(26.3k)
Manager: W. Price, B.C. MEMPR
Contractor: Norecol

Objective:

- Complete long-term testing of waste rock in the Cinola Gold columns and humidity cells (including archived samples) and monitoring of on-site waste rock piles.
- Compare laboratory and data with field observations.
- Dismantle weathering columns and analyze residues from both the columns and the waste rock piles.

Status:
Some of the more advanced and long-term work in prediction of acid mine drainage has been conducted for the Cinola Gold Project including column experiments to investigate the effect of limestone blending, humidity cells to examine the long-term acid production potential of marginal (by acid base accounting standards) waste material, and field waste rock piles to study the relationship between laboratory and field acid production. Prior to the initiation of this project, which is near completion of its final year, these tests had already been running for more than two years.

1990/91: The condition of the waste rock pads were examined. A monthly leachate sampling program was initiated. Monitoring of the limestone columns for pH and conductance, measurement of general parameters (sulphate, acidity, alkalinity, calcium, iron) was done every forth week. Analysis of all archived leachate and archived dissolved metal samples that were collected quarterly was completed.

1991/92: Monitoring of the limestone and rock mixing column experiments, and

the waste rock pads was continued. Leachate from the columns and pads have been analyzed for; pH, conductivity, sulphate, acidity, alkalinity, Ca, and a suite of dissolved metals.

1992/93: Kinetic tests and monitoring will be completed. Dismantling of the test apparatus will be followed by analyses of the weathered material from the columns and from a representative pile. A comprehensive analysis of the data collected (both laboratory and field) will conclude this program. The waste rock piles will be maintained to allow future monitoring if required.

ACTIVE PREDICTION - Modelling
March 1993

Project 1.21.1d:	ß-Evaluation of Tailings Model - RATAP.BMT3
Budget:	$15,000
Sponsors:	..... CANMET
	$15,000
Expenditures:	$3,000
Manager:	H. Steger, CANMET
Contractors:	USBM, Noranda Technology Centre, University of Waterloo

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Objective:

To evaluate the responsiveness of the model RATAP.BMT3 (Reactive Acid tailings Assessment Program for Base Metal Tailings) as a predictive modelling tool to meet the needs of the user, both industry and regulatory.

Status:

RATAP was formulated to answer a number of fundamental questions regarding rates of sulphide oxidation in tailings and the resultant concentrations of available contaminants. Based on recommendations made at a workshop (1.21.1b), user-friendly input (FRONTEND) and output (GRAPH) modules were added and a user's manual written. It was recommended that the final version of the overall model be evaluated with respect to: how well the model can be used to address the fundamental questions for which it was formulated; with what ease the model and outputs can be manipulated; and further capabilities and/or limitations which should be noted by future users.

The RATAP.BMT3 model is being evaluated by three independent groups. The report on the beta-test from the Noranda Technology Centre has been received. The beta-testing at the University of Waterloo is complete and awaits the preparation of the report. The U.S. Bureau of Mines has done only preliminary work due to time constraints and computer software faults incurred during shipping. Attempts will be made, however, to carry out some testing of the input and output modules. A deadline for submission by the latter two contractors was set for the end of February, 1993.

Over and above the scope of this project, CANMET is addressing some of the comments of the beta-test report from the Noranda Technology Centre. A large effort has gone into the development of a menu-driven system to increase the flexibility of RATAP. The objective is to disconnect the current sequential

interfacing of the FRONTEND, RATAP, and GRAPH modules to give the user direct access to these modules for creating input files, running the model, directing output files to storage and plotting the output.

A plan to address the comments of the beta-test reports will be prepared by CANMET by the end of March, 1993.

ACTIVE PREDICTION - Modelling
March 1993

Project 1.22.1: ANSTO Model at Heath Steele
Budget: $145,000
Sponsor: ..... CANMET $85,000
New Brunswick $25,000
Noranda $65,000
Expenditure: $26,000
Manager: E. Yanful, Noranda
Contractor: Nolan Davis & Associates
Australian Nuclear Science & Technology Organization
Noranda Technology Centre

Objective:

To better understand the inter-relationships governing gas and heat transport in (potentially) acid-generating waste rock piles and to develop guidelines for optimizing pile construction and cover systems to inhibit oxidation within the waste rock piles.

Status:

The program is addressing the issue of gas transfer in acid waste rock piles and the application of a computer model developed to address oxygen and heat transfer mechanisms (diffusion, convection, advection) therein. Data and experimental opportunities provided by the ongoing Heath Steele waste rock project in New Brunswick are being incorporated. The project is being undertaken cooperatively by Nolan, Davis and Associates, and the Australian Nuclear Science and Technology Organization (ANSTO) who have developed the FIDHELM model. After characterization of the gas transfer relationships, the model is to investigate, under Canadian climatic conditions, the potential of isolating active material in the dump, different construction methods, and the application of cover systems.

The installation of six monitoring wells in the uncovered pile 18B was completed in June, 1992. Subsequent in situ measurements of gas permeability, thermal conductivity and gas diffusion were made by ANSTO, assisted by Nolan Davis. The procedures used are being documented. The temperature and oxygen probes attached to the monitoring wells have been monitored by telemetry on a monthly basis since installation, in conjunction with another ongoing project at Heath Steele(2.31.1).

ANSTO has made a preliminary analysis of the Heath Steele waste rock piles using the FIDHELM model which identified the sensitivity of the pile to various parameters which were measured over the summer of 1992. ANSTO will be carrying out detailed analyses of each of the four waste rock piles under study at Heath Steele using the field measured parameters for gas permeability, thermal conductivity and gas diffusion. The project is expected to be complete by the middle of 1994.

ACTIVE PREDICTION - Chemical Prediction
March, 1993

Project 1.23.1: Compilation of Rules for Prediction of AMD
Budget: $30,000
Sponsors: British Columbia $5,000
CANMET $5,000
Expenditures: $10,000
Manager: W. Price, B.C. MEMPR
Contractor: L. Broughton

Objective:

To compile and organize the "rules", conventions and practices commonly used for the prediction of acid rock drainage by geologists, regulators, consultants and researchers. If considered applicable based on a go/no go decision, develop an expert system to aid in the selective application of these rules in the assessment of predictive data.

Status:

New mine projects rely primarily on the results of chemical tests such as geochemical, static and kinetic methods for acid mine drainage prediction. Several rules, tools and "tricks of the trade" have been developed to interpret these test results. A number of these rules and approaches have been compiled.

A review of the literature was carried out as well as interviews with key researchers to identify and document interpretive rules being used. The interpretive techniques have been documented and some level of relative "certainty" has been assigned.

The development of this rule base has indicated a number of trends and issues in ARD prediction: increased use of mineralogy and petrography for interpretation; interpretation of static test results based on both net neutralizing potential and the ratio of neutralizing potential versus acid-generating potential; rejecting predictive generalizations between waste rock and tailings are inappropriate; use of appropriate sampling procedures; and the extrapolation of kinetic test results to long-term field conditions.

The generation of an expert system, a logical and linear progression of rules based on the rule base generated through the first phase of this work, is considered premature and is not recommended at this time.

A draft report has been completed. Recommendations based on a review of this report are being taken into consideration in the finalization of the report.

ACTIVE PREDICTION - Modelling
March 1993

Project 1.25.1a: Development of a Soil Atmosphere Flux Model for Design of Sulphide Tailings Cover Systems - Phase I
Budget: $49,500
Sponsor: ..... CANMET $55,800
Expenditures: $49,000
Manager: M. Blanchette, CANMET
Contractor: University of Saskatchewan

Objective:

To develop a program for the computation of moisture fluxes between tailings, cover systems and the atmosphere based on routine climate data and soil properties.

Status:

Carefully designed soil cover systems may be used as oxygen barriers in the control of acid mine drainage, the success of which will depend on climatic conditions and cover system properties. The development of a tailings-cover-atmosphere flux model enhances the ability to optimize design of such cover systems. A mechanistic model for evaluating the flux boundary conditions and the soil-atmosphere interface, developed at the Universities of Manitoba and Saskatchewan, has been used as a basis.

The mathematical derivation and formulation of the finite element solution for coupled heat and mass transfer in soil covers has been completed successfully. The Soil Atmosphere Flux model is currently running on PC/DOS computers and is being tested for numerical accuracy. The program has been tested by comparing its solution with those computed by other, well established methods. It is expected that the program and user's manual will be completed, on schedule, by end of March, 1993.

Some servicing and updating of the Soil Atmosphere Flux model may be required after the delivery of the program. For example, it is difficult to ensure that the program will run without error or fault for all computer systems and field applications. Some provision for time to ensure the program is functioning properly may be necessary before release for general use by the mining industry.

A decision to continue with the development of the model to accommodate water flow and hydraulic effects under freezing conditions will be made in future. This phase would be expected to require an additional two years to complete.

ACTIVE PREDICTION - Modelling
March 1993

Project 1.26.1: Development of a Modelling Methodology for Prediction of Seepage Quality from Acid-Generating Waste Rock - Phase I
Budget: $90,000
Sponsors: British Columbia $60,000
Environment Canada $30,000
Expenditures: $30,000
Manager: W. Price, B.C. MEMPR
Contractor: Steffen Robertson & Kirsten

Objectives:

To develop a preliminary model based on the current state-of-the-art for predicting drainage water quality from waste rock dumps using existing theoretical and empirical relationships, and, to determine the level to which a waste rock model can be developed to predict numerical values for the water chemistry of drainage from waste rock piles.

Status:

The project, based on the recommendations of 1.24.1, was defined to include the following tasks:

- comprehensive compilation and review of existing applicable information;
- development of a preliminary model including: specific components of the dump characterization model; the acid generation and flow path reactors within the dump; the downstream reactors including surface and subsurface mixing and flow; and the receiving environment component;
- definition of further data and/or research required; and
- detailed recommendations for further development of the modelling capability.

A draft report, Rock Pile Water Quality Modelling - Phase I, has been received and reviewed by members of the MEND and B.C. AMD Prediction committees. The report provides a description of the process of acid generation and contaminant migration; outlines an overall framework for model development; provides a summary of the general state-of-the-art for the various elements of model development; describes the modelling methodology currently used by the authors; and identifies the areas requiring additional research and model development.

A compilation of revisions and additions required to the draft report have been submitted to the contractor. The approach to the generation of an applied waste rock model is still believed to be appropriate. In general, the comments focus on the need for an unbiased, properly documented and referenced document which is founded on supportable evidence.

Further work as recommended by the contractor in the report, is not being considered at this time.

ACTIVE PREDICTION - Basic Research
March 1993

Project 1.31.1: Fundamental Reaction Kinetics Study of Weathering Employing SIMS
Budget: $95,000
Sponsors: Echo Bay
$ 5,000

Ontario	$53,500
DIAND	$18,000
INCO	$14,000

Expenditures: $51,000
Manager: M. Blanchette, CANMET
Contractor: Klohn Leonoff/University of Western Ontario

Objective:

To demonstrate the potential of Secondary Ion Mass Spectrometry (SIMS) in the prediction of acidic drainage in weathered and non-weathered mine tailings and waste rock.

Status:

Secondary Ion Mass Spectrometry has the capacity for analyzing the top 30-40 Angstrom layer of particle surfaces and determining element concentrations at detection levels of less than 1 mg/kg. Through SIMS, composition of near-surface layers can be obtained versus depth profiles. Other surface-sensitive techniques, such as x-ray photoelectron spectroscopy (XPS) and auger electron spectroscopy (AES), are being used in the delineation of reaction mechanisms occurring at or near particle surfaces.

As of the end of December, 1992, nineteen weeks of the thirty-week weathering program have been completed for the tailings from the Lupin mine, North West Territories. Due to the late delivery of waste rock samples from northern Manitoba, the weathering tests of the waste rock are nine weeks behind. Project extension to cover the full weathering program for waste rock is being considered. The staged weathering approach involves: two week leaching program using deionized water; eight week leaching program using various dilute solutions according to standard wet/dry humidity cell protocol; and a twenty week flooded leaching program. The weathered material will then be analyzed, both macroscopically and via surface analysis techniques.

The University of Western Ontario has completed the examination of fresh and oxidized surfaces of three sulphide minerals present in the Lupin mine fresh tailings, namely arsenopyrite, pyrrhotite, and pyrite. The pure minerals were freshly fractured under high vacuum conditions (10^{-7} Pa) and oxidized under controlled atmospheric conditions and timed exposure to air. The samples were then analyzed using XPS and AES techniques. Air oxidized samples develop surfaces with thin layers of α-Fe_2O_3 coating iron deficient sulphide, suggesting cation migration from the underlying sulphide to the surface oxide layer. Migration of iron to the surface yields a sulphur-rich layer just below the oxide layer.

ACTIVE PREDICTION - Basic Research
March 1993

Project 1.32.1: Prediction and Prevention of Acid Rock Drainage - A Geological and Mineralogical Approach

Budget: $73,000

Sponsors: BHP Utah
$ 3,230

Cominco	$ 3,230
Environment Canada	$55,000
Homestake Canada	$ 3,230
HBM&S	$ 3,230
Placer Dome	$ 3,230
Teck	$ 3,230

Expenditures: $70,000

Manager: M. Blanchette, CANMET

Contractor: National Hydrology Research Institute

Objective:

The objectives of this program are to determine:

- the tendancy of major types of metallic sulphide deposits to generate acid;
- relative oxidation rates of individual sulphide species in polysulphide assemblages; and
- initial field measurements and laboratory analyses needed to asses the acid generation potential and expedite the environmental impact assessment process.

Status:

The draft report of the field and laboratory work is currently under peer review. Seven types of metallic mineral deposits have been ranked according to their ARD potential based on: field examination at ten operating, developing and abandoned minesites; natural ARD studies; and a literature review. A formula for assessing ARD potential based on the entire main mineral assemblages is suggested.

Weathering experiments using polished thin sections shed new light on the relative weatherability of common sulphides. In addition to bulk chemical composition, grain size, crystallinity, the trace element content, crystal structure and deposition history are shown to have an influence on the weathering rates.

Prediction and prevention of ARD at a minesite can be improved by the mine geologist's knowledge of the mineral distribution, areal change in lithology and structural geology of the site. At the exploration stage, incorporating simple waste quality measurements like pH, Eh and conductivity in the geological mapping exercise can lead to an early assessment of ARD potential. It is evident that chemical, microbial and electrochemical processes rarely occur independently in the oxidation of sulphides as shown by field observations and results of weathering experiments conducted during this study.

ACTIVE **P&C** - **Wet** **Barriers**
March 1993

Project 2.13.1:	Flooding of Existing Tailings Sites - Quirke Lake	
Budget:	$835,000	
Sponsors:	Rio	Algom
	$502,000	
	CANMET	$333,000
Expenditures:	$835,000	
Manager:	A. Vivyurka, Rio Algom Limited	
Contractors:	Rio Algom Limited/CANMET	

Objective:
The objective of this project is to investigate the feasibility of establishing a wet barrier, such as a water and/or wetland cover on pyritic uranium tailings to:

- act as an oxygen barrier, and hence control acid generation;
- stabilize the tailings surface; and
- minimize surface and groundwater contamination.

Status:
During the spring of 1989, Rio Algom and CANMET began a three-year joint project to assess the feasibility of flooding the existing Quirke tailings site as a close-out option. To date the following has been completed:

- literature review on wetlands and their role in treating acid mine drainage;
- field evaluations of wetland sites (hydrogeochemical and biological characterization);
- wetland vegetation transplantation, survival and propagation studies on tailings;
- column leaching lysimeter tests (oxidation, leaching and neutralization characteristics);
- preparation of a large-scale field demonstration program (65 ha). This included levelling of the tailings surface, limestone addition, liquefaction study, piezometer installation, flow control structure, continued sampling and a monitoring program to be implemented during flooding; and
- design and construction of 4 field tests plot (in triplicate) for tailings with shallow, wetland and municipal compost covers and monitor. The fourth is the control.

A piping failure in November 1990 and a leak in a dam foundation in late 1991 have prevented the flooding of the 65 hectares test site. Repairs were completed and flooding commenced in November 1992. Testing of the cover will be two

years behind schedule.

Work that is scheduled for 1993 includes:

- monitoring of the cover, the four field test plots and the laboratory columns; and
- preparation of the final report on both the field and laboratory studies.

A recommendation that could be considered, pending the reception of a final report, is for an additional year or two of monitoring the water cover and test plots.

ACTIVE **P&C** - **Wet** **Barriers**
March 1993

Project 2.13.2: Flooding of Existing Tailings Sites - Solbec Cupra
Budget: $260,000 (1992 - $ 24,812)
Sponsors: .....Cambior
$12 411
Québec..... $12,411
Expenditures: $157,812
Manager: L. Bienvenu, Centre de recherches minérales
Contractor: Roche Ltée.

Objective:

The objectives of this project are to determine if a water cover prevents the continued oxidation of acidic tailings (with ≈30 to 50% sulphide), and to establish the minimum water depth needed, while considering wind, waves, permeability of the sub-soils and the hydrology of the drainage basin.

Status:

The first phase of the MEND project (1990) involved the installation of an instrumented experimental basin with watertight sides (geomembrane). This basin had a lower layer of non-oxidized tailings overlying the till, and an upper layer of oxidized tailings. A continuous one-metre water cover was provided by gravity flow. Results confirmed that a water cover prevents the oxidation of fresh tailings. However, porewater samples taken in the oxidized tailings are acidic, even after flooding.

In 1991 a contract was let to complete a hydrogeological study of the tailings basin to assess the suitability of flooding. This involved the installation of an additional basin with instrumentation and a seismic survey to determine material properties and monitoring. Results indicate that flooding of the tailings site is possible with natural precipitation and surface runoff over a two year period. Construction of impervious dams at the north end of the tailings pond and/or levelling of the tailings surface at the south end will be required to maintain a water cover of one metre on the tailings.

The 1992 program involved the installation of another basin where lime has been added to the oxidized tailings. Monitoring of all field lysimeters has also continued and will continue in 1993. Preliminary results are not available at this time. Two other areas that will be studied in 1993 include the chemical and microbiological

considerations of flooding the site and an evaluation of the optimum depth of water required to prevent resuspension of solid particles through wind action.

ACTIVE P&C - Dry Barriers
March 1993

Project 2.21.2:	Engineered Dry Covers for Tailings - Noranda
Budget:	$348,000
Sponsors:	
	Noranda $157,000
	CANMET $136,000
	Québec $126,000
Expenditures:	$419,000
Manager:	E. Yanful, Noranda Technology Centre
Contractors:	Noranda Technology Centre
	McGill University/École Polytechnique

Objective:

As a complement to the laboratory evaluation of cover materials (Project 2.21.1), Noranda is evaluating the effectiveness of engineered dry covers in reducing acid generation in reactive tailings at the Waite Amulet site.

Status:

The design, construction and instrumentation of the test plots was completed by the fall of 1990. The four field test plot covers are comprised as follows: 2 composites of fine-grained soil layer underlain and overlain by coarse-grained layers; a composite of a geomembrane (HDPE) underlain and overlain by coarse-grained soil layers and one uncovered plot (control). Each cover is designed to have a low hydraulic conductivity and a high degree of saturation to minimize infiltration and oxygen movement. The field plots are instrumented to allow monitoring of gaseous oxygen, carbon dioxide, temperature and porewater. Porewater will be analyzed for pH, acidity, sulphate and heavy metals. Laboratory lysimeter tests are conducted at Noranda Technology Centre to simulate the various field cover scenarios.

Several other parallel studies have also been commissioned. They are:

- Monitoring the changes in the concentration of sulphur bearing gases in the cover layers and evaluating their effects on the integrity of the cover;
- In situ monitoring in the vicinity and below the cover to analyze the effects of the cover and for modelling;
- Flow modelling of moisture and oxygen through the cover;
- Geochemical modelling; and

· Laboratory freeze/thaw on the clay layer and the composite cover layer.

Work that is to be completed in 1993, the final year of the project, includes:

· Continued monitoring of the cover performance; and

· Submission of an interim report on the construction of the piles in the spring and a final interpretation report during the summer of 1993.

ACTIVE P&C - Dry Barriers
March 1993

Project 2.22.2: Evaluation of Dry Covers Built from Mine Tailings
Budget: $234,880 (1992 - $127,880)
Sponsors: .....Québec
$121,880
Ressources Ste-Geneviève ..... $ 6,000
Expenditures: $127,880
Manager: L. Bienvenu, Centre de recherches minérales
Contractor: École Polytechnique

Objective:

The objective of this study is to evaluate, under controlled laboratory conditions, the effectiveness of using mine tailings as an alternative material in cover construction to control acid mine drainage (AMD).

Status:

In most of the projects currently underway in Canada and abroad, dry barriers are usually constructed from naturally occurring geological materials (till, silt or clay) maintained at a high degree of saturation to minimize the diffusion of oxygen through the cover. Under most conditions, granular materials would be expected to drain to residual saturation allowing a significant amount of oxygen to enter the voids. By creating layers of fine-grained over coarse-grain materials, the fine layer can be maintained in a saturated state regardless of the depth of the water table. Because low permeability soils may not be readily available at many sites, alternate materials (e.g. mine tailings) having somewhat similar physical properties may be substituted.

A preliminary project, and the first year of the present study are completed. More than 30 tailings sites were sampled and analyzed as possible cover materials and a state-of-the-art literature review were completed. The results confirm that sulphide-free fine tailings offer some promising characteristics as cover materials. For instance, it has been shown that, when the void ratio is reduced, the permeability of tailings can be as low as 1×10^{-6} cm/s, which compares very well with that of silts and tills. Also from the sieve analyses and available data in the literature, it is expected that fine tailings can maintain a high degree of saturation when they are used in a layered system because of their relatively high water retention capacity. Recent work described in the literature shows that silty soils, with physical properties similar to some of the tested tailings, can be used with success to limit

AMD.

Four tailings sites were retained from the 30 analyzed samples for geotechnical, hydrogeological and mineralogical characterization. These will also be subjected to some column tests and some preliminary modelling of a proposed cover design will be done in the second year of the project.

ACTIVE **P&C** - **Others**
March 1993

Project 2.23.3: Porous Envelope Surround Disposal Method - Falconbridge
Budget: $123,000
Sponsor: ..... Falconbridge
$70,200
Ontario $52,800
Expenditures: $123,000
Manager: M. Wiseman, Falconbridge
Contractor: Noranda Technology Centre
Geomar Geophysics Ltd.

Objective:

The objective of this project is to evaluate the feasibility and effectiveness of the porous envelope surround disposal concept for controlling acid mine drainage.

Status:

The porous envelope concept is based on the fact that groundwater flow into low permeable tailings masses can be minimized if highly permeable materials are placed adjacent to and surrounding the tailings. If differences between the adjacent material and tailings permeability are sufficient, groundwater penetration into the tailings mass will be eliminated or reduced to acceptable levels.

Preliminary observations at Falconbridge's Fault Lake tailings pond suggest that permeability contrasts between the natural till deposits and the tailings may be sufficient for porous envelope containment to occur.

In an effort to minimize costs, Falconbridge has had electromagnetic surveys (Fixed Frequency Electromagnetic (EM) profiling or Transient Electromagnetic (TEM) sounding) completed at the site. These non-intrusive techniques were cost effective in identifying groundwater contamination plumes thus facilitating the installation of the required scientific equipment in 1992 in the areas identified by the survey. Both the EM and TEM reports will be published under a single cover in 1993.

Stage II of the project, following the installation of the monitoring equipment, involves the measurement of hydraulic properties, hydrogeological analysis with numerical modelling and chemical monitoring of appropriate parameters existing on site for a period of at least one year. The estimated cost for Stage II is approximately $50,000 more than proposed. The depth to the water table was

greater than anticipated, thus the costs of the monitoring wells were higher and the EM survey identified an additional seepage path resulting in extra wells being installed. A progress review is planned on this project at the next P&C meeting and a decision will be taken on additional funding approval.

Stage III, if it is required, involves installation of a cover. A go/no go decision will be taken following Stage II.

ACTIVE P&C - Dry Barriers
March 1993

Project 2.25.1: Reclamation of Sulphide Tailings Using Municipal Solid Waste Compost
Budget: $130,000 (1992 - $56,000)
Sponsors: ..... Falconbridge $43,500
Ontario $32,500
Expenditures: $56,000
Manager: M. Wiseman, Falconbridge
Contractor: Laurentian University
Waterloo University

Objective:

The objective of this study is to conduct laboratory and field scale demonstrations on the use of municipal solid waste compost as an abandonment strategy for mine tailings.

Status:

The first stage of the project was to conduct a literature review of what is known about the physical and chemical characteristics of municipal solid waste (MSW) compost and other organic materials. This review revealed that a compost layer on tailings could be beneficial as a physical oxygen barrier, an oxygen-consuming barrier, for chemical inhibition, for chemical amelioration and for reduced water infiltration. A copy of the literature review and recommendations report will be available from CANMET in 1993.

Experimental investigations in the laboratory are required to assess whether the compost cover layer will function as expected, in the field. The second stage will try to obtain answers to technical questions about the optimal cover layer design and safety of using a cover of MSW compost as a permanent solution to prevent acid drainage from tailings. This includes physical and chemical evaluations of compost, compactability, leachate composition at varying degrees of maturity, ability to retain moisture and maintain anaerobic and/or reducing conditions and optimization of the compost cover layer thickness. This work was started in 1992 and will be continuing in 1993. Early results indicate metal concentrations in MSW leachates are very low. Future studies will include the determination of organic contaminants in the leachates.

A go/no go decision will follow the completion of the laboratory work. Stage 3 is the construction of field lysimeters at the Nickel Rim tailings site to simulate field conditions.

Concurrent with the first three stages of this study, Falconbridge has initiated a detailed field study to obtain background data at the Nickel Rim site to supplement their existing database. This includes a list of potential compounds found in MSW. The University of Waterloo is carrying out this background data collection study.

ACTIVE P&C - Waste Rock
March 1993

Project 2.31.1b:	Dry Covers on Waste Rock - Heath Steele
Budget:	$367,700 (1992 - $48,000)
Sponsors:	Noranda - BM&S (Heath Steele) $121,300
	CANMET $154,500
	New Brunswick..... $ 91,900
Expenditures:	$246,000
Manager:	E. Yanful, Noranda Technology Centre
Contractors:	Nolan Davis and Associates
	Heath Steele Mines

Objective:

The objective of the project is to evaluate the effectiveness of a soil cover as a method of long term management of acid-generating waste rock. Project 2.31.1b consists of applying the cover, designed in Project 2.31.1a to Pile 7/12 and monitor the cover performance for three years.

Status:

Work started on the cover in August, 1991. The surface of the pile was prepared and those materials not available on site were purchased (-35 cm crushed stone, coarse sand, pit run and -2 cm clean crushed gravel). Clayey till was found about 2 km from the site. A test strip, next to the pile, was used to determine the optimum number of passes needed by the roller to obtain the desired compaction with the required moisture content. The cover and instrumentation was completed in September 1991. One complete year of monitoring on the test pile has been completed. A second pile used as a control is also being continuously monitored. A draft report on the construction and placement of the cover was received from the contractor in February 1992. This interim report will be revised to include the construction plus one year of monitoring data and would be made available through MEND (summer 1993).

Activities for 1993 and the two following years are concentrated on monitoring of the pile, compiling information and reporting on results.

The monitoring program will determine the rate of oxygen and moisture ingress to the pile through the cover and continue to monitor the processes within the pile through temperature and oxygen profiles. Local meteorology and leachate generation from the pile will also be monitored.

The final output from this project will be a performance evaluation report describing the effectiveness of engineered natural covers on waste rock. The collected data will also be used in a design criteria document that can be used for construction purposes.

ACTIVE P&C - Waste Rock
March 1993

Project 2.35.2a,b: Lysimeter Evaluations of Cover Alternatives - Noranda
Budget: $145,000
Sponsors: Noranda Technology Centre $92,700
Québec..... $52,300
Expenditures: $120,500
Manager: E. Yanful, Noranda Technology Centre
Contractor: Noranda Technology Centre
McGill University

Objective:
The objective is to evaluate the relative effectiveness of different measures in preventing and controlling sulphide oxidation and hence acid generation in waste rock under field conditions.

Status:
The experiments were started in June 1991 and weekly monitoring of the drainage water from the lysimeters have been in progress since then. The control techniques being investigated are water cover, soil cover, wood bark cover, and addition of limestone and phosphate rock (apatite). Potentially acid-generating waste rock samples used in the investigation were obtained from the Stratmat mine in New Brunswick and from a Québec-based mine. The investigation involved outdoor lysimeter tests and indoor laboratory column experiments.

Monitoring of the effluent water quality up to about 60 weeks indicated the control waste rock started producing acid very early in the tests (≈ 5th week). The rate of acid production was quantified and found to be higher in the laboratory than outside. Higher laboratory temperatures are most probably the reason for the higher rate.

The most effective control technique over a 60-week period was water cover, followed by 3% and 1% limestone, soil cover and, finally 3% and 1% phosphate. All the techniques, with the exception of the water cover (same results), were found to be slightly more effective in the laboratory than outside. In these tests it was found that the wood bark accelerated acid production in the laboratory and outside. The organic nutrients from the wood are believed to have promoted the iron oxidizing bacteria (*Thiobacillus ferrooxidans*) and this may explain this acceleration. Different results are being observed for wood bark covers in Project 2.25.2. The difference is probably explained by oxidizing conditions in the lysimeters versus reducing conditions in the field.

Aqueous geochemical modelling of the effluents has just begun. Monitoring will be continued for a further two-year period as part of the ongoing work to establish the effectiveness and longevity of the techniques in controlling acid production. Future proposed work (Project 2.35.2c) will also include a detailed interpretation of the geochemistry of the various metals in the drainage water.

The first milestone report was submitted to MEND in December 1992 and is being reviewed. Copies of the report will be available from CANMET in 1993.

ACTIVE **P&C** - **Others**

March 1993

Project 2.42.1a: Development of Synthetic Polymers - Laurentian
Budget: $45,000 (2.42.1a)
$38,000 (2.42.1b)
Sponsors: ..... INCO
$22,500
Ontario $22,500
Expenditures: $31,150
Manager: B. Bell, INCO
Contractor: Laurentian University

Objective:

The project objective is to synthesize a polymeric material(s) with specific engineering characteristics. The ideal material(s) would have the following properties, in tailings ponds, it would: a) be water soluble; b) provide long-term bactericidal action; c) strongly adsorb into particulate matter; d) flocculate fines when wet; e) act as a binding agent for fines when dry; and f) complex any previously leached metals. In waste rock it would also: g) be readily foamed to allow penetration into the pile; and h) have virtually no oxygen permeability.

Status:

This project started more slowly than anticipated because of difficulty in arranging for appropriate graduate student participation. This has now been resolved and the contractor has three full-time graduate students working on the project.

A number of approaches have been tried in synthesizing various components of the required polymer(s). As anticipated, most were not effective and efforts have been focused on those showing significant results. To date the major achievement has been the synthesis of a new inexpensive polymer that precipitates a number of metal ions, including copper, nickel, zinc and manganese. Efforts are continuing to synthesize an appropriate polymer incorporating the EDTA structure.

This is a three-year research project, of which the first two years are MEND-approved. A go/no go decision is incorporated into the program at the end of each of the first 2 years. Because of the slow start-up problems, the first go/no go decision (Project 2.42.1b) has been deferred to the end of March 1993. No further funds will be allocated until after that time.

ACTIVE **TREATMENT**

March 1993

Project 3.11.1d: Treatment of Acidic Seeps Employing Wetland Microbiology (ARUM)
Budget: $80,000 for 1992 (final year)
Sponsors: Environment Canada $20,000

CANMET	$20,000
INCO	$20,000
Québec	$20,000

Expenditures: $60,000
Manager: T. Hynes, CANMET
Contractor: Boojum Research

Objective:

The objectives of this project are to establish the fundamentals of the microbiology and ecology of engineered wetland, and to determine the design parameters required to establish self sustaining systems to treat acid mine drainage.

The objective for the final year is to complete the field work, determine the design parameters for such a system and to evaluate its applicability.

Status:

This 4-year project had been subjected to an independent Peer Review early in 1991. The reviewers found, with minor variations, that the quality of the scientific work was acceptable and was following a correct direction. During 1991, some additional difficulty had been experienced by the contractor in maintaining a steady flow, but by late summer the system had been stabilized. The Treatment committee carefully reviewed the progress of the work and recommended unanimously that the work be wrapped up in 1992, with the 1992 emphasis being placed on design parameters for application of the technology at active or decommissioned and abandoned sites.

In January 1993, a report was received that summarized the 1992 field season data. Again some very good water quality results had been achieved, but at low flow rates.

A final summary report is expected at the end of March 1993. This report will:

- summarize the field observations and measurements over 4 years in the field;

- determine the operating parameters for the ARUM system;

- produce design criteria and conceptual design; and

- estimate operating costs.

ACTIVE **TREATMENT**

March 1993

Project 3.12.2: Evaluation of Wetlands at Panel "A" Site
Budget: $45,000
Sponsors: ..... CANMET
$22,500
Ontario $22,500
Expenditures: $45,000
Manager: H. Rabski, MNDM Ontario
Contractor: CANMET - Elliot Lake Laboratories

Objective:

The objective of this study is to establish if an existing natural wetland at Elliot Lake provides significant treatment and control over water quality parameters associated with the oxidation of pyritic tailings and migration of contaminants. This study will incorporate surface and sub-surface hydrogeochemistry and vegetation and substrate characterization for their role in various geochemical and biological interactions.

Background:

A preliminary water quality survey in 1989 had revealed a dramatic improvement in pH from 3.6 to 6.6 and electrical conductance "Ec" from 1100 to 260 μS, as the water moved from the exposed western section to the eastern water logged area. In summer and fall of following years, the water quality parameters were respectively pH 4.4 to 8.1, and Ec 185 to 1271. This large site supports a very healthy, dense and self-sustaining vegetation consisting of cattails and filamentous moss with an organic layer 15cm in height, on top of unoxidized tailings slimes.

Status:
Surface and groundwater samples and sediments have been analyzed to evaluate the role of natural wetlands in providing treatment and control for tailings partially submerged. Solid core sediment samples are also analyzed for total sulphide content and microbe (both *Thiobacillus ferrooxidans* and sulphate reducers) population densities.

The results have confirmed that the wetland is continuing to improve water quality, and that nitrogen compounds are instrumental in this improvement. Also, the some dilution has been observed and this accounts for the observed decrease in dissolved salts such as chloride not effected by microbial activity, such as chloride.

It has been shown that where the aquatic plants are rooted into the tailings sediments, sulphide oxidation continues, although at a slow rate. However, where the plants are floating above the tailings, sulphate reduction is occurring, and heavy metals are being precipitated.

The final report will be completed by March 30, 1993. The results will be valuable in assessing the use of natural wetlands and in designing shallow water covers.

ACTIVE **TREATMENT**

March 1993

Project 3.13.1a: Passive Treatment of Small Seeps
Budget: $90,000
Sponsors: .....Noranda
$60,000
CANMET $30,000
Expenditures: $90,000
Manager: Grant Feasby
Contractor: Noranda Technology Centre

Objective:

Evaluate and demonstrate the applicability of various passive, low-cost processes for treating small volumes of acidic seepage.

Background:

Passive treatment processes are under development in Canada and the United States and these include anoxic limestone trenches, lime organic beds, biotrenches, and biobeads. The ARUM process (Project 3.11.1) although shown to be effective at small flows, may need frequent care and attention. There was a need to evaluate the various technologies available and to determine applicability in the colder Canadian environment.

Bench-scale treatment tests were carried out at Noranda Technology Centre in 1992 to evaluate 4 passive treatment methods. Process parameters such as pH, acidity, Eh, metal & sulphate concentrations, flow rates and hydraulic characteristics were determined. A New Brunswick site would be considered for field work.

Status:

A draft report has been received and is being reviewed. The results show that there are
three processes that have been developed in the United States that have potential application for treating small streams with strong concentrations of acid mine drainage. They are lime-organic mixtures, anoxic limestone trenches, and biosorption systems.

The contractor recommended that additional laboratory studies be completed before going to the field, and that combinations of two of the above processes may be

needed to cope with the cold temperatures found in the field and with the variable flows.

The Heath Steele mine site in northern New Brunswick is believed to be an ideal field site for evaluating the application of these methods to treat small or "nuisance" seeps. There exists at Heath Steele several small acid drainage seeps that have resulted from mining activity, the use of sulphide wastes in construction and undisturbed seeps from rock fissures.

ACTIVE **TREATMENT**

March 1993

Project 3.21.1b: Removal of Metals from AMD - Ion Exchange
Budget: $75,000
Sponsors: ..... Teck $10,000
Falconbridge ..... $ 4,000
Ontario $25,000
Expenditures: $4,000
Manager: P. Kondos
Contractor: CANMET

Objectives:

Assess and demonstrate the applicability of ion exchange to remove selected metals from acidic drainage. The process of metals removal will significantly lower the metal content of subsequent treatment sludges.

Background:

Removal of metals from acidic drainage effluents will allow treatment plant operators to generate treatment products which do not in the long term pose the risk of generating a toxic effluent. This would provide the walk-away closure scenario at a site where when acidic drainage is effectively stopped, and the lime treatment plant is shut off. Little to no care and maintenance of treatment sludge ponds would be required. Since "walkaway" at minimum cost is the property owner's prime decommissioning objective, application of ion exchange technology for metals removal was proposed.

Status:

Four samples of AMD have been obtained for bench scale screening tests on 6-8 resins. Small scale continuous tests, where iron oxidation chemistry is closely controlled to simulate field conditions, will be done. Larger scale (up to 0.5 l/min) lab tests to simulate loading, elution, recycling and recovery of metals for disposal or sending to a smelter will be completed.

Data will be developed on the potential use of ion exchange to reduce metal content (Ni, Cu, Zn, Pb, Cd) of treatment products. Recommendations on possible pilot work will be made.

ACTIVE **TREATMENT**

March 1993

Project 3.21.2a: Removal of Metals from AMD - Chemical Treatment

Budget: $100,000
Sponsor: .....Noranda
$90,000
Expenditures: $90,000
Manager: N. Kuyucak
Contractor: McGill University
Noranda Technology Centre

Objectives:

To develop and evaluate the processes for separation of toxic metals from typical acid mine drainage by selective precipitation techniques.

Background:

In almost all cases where there is potential for the mineral wastes to produce acid mine drainage, there will be some quantities of AMD to treat, irregardless of what control technology is put in place. In several instances, the metal content is high enough that the precipitation of the metals with lime or collection by other agents could result in high metal concentrations in unstable sludges.

Initial background work at McGill had shown that selective precipitation of ferric iron, aluminum and zinc was possible. Special techniques need to be applied to selectively remove copper.

Status:

A bench scale investigation has been carried out to optimize the initial flowsheet of separating iron as the hydroxide using lime/amine combinations and developing solid/liquid separation techniques. Copper and zinc have been removed as the sulphide, and techniques have been tried to produce a precipitate that can be recovered as a low-moisture sludge. Techniques have been examined for selective removal of zinc and copper with lime, and the potential for incorporating these specific sludges in a smelter feed is being evaluated.

Dodecylamine has been shown to be effective in improving the process of sulphide precipitation of copper and zinc. "Final effluent quality" has been achieved but

further work is indicated needed on settling characteristics and stability of precipitates.

The final report will be complete by April 1993. Either ion exchange or chemical treatment for metals removal are to be piloted in the future under MEND at an estimated cost of $130,000.

March 1993

Project 3.31: Use of Lime Sludges for Capping
Budget: $20,000
Sponsor: .....INCO
$7,000
Ontario $7,000
..... CANMET
$7,000
Expenditures: $5,000
Manager: Tom Hynes, INCO
Contractor: Laurentian University

Objective:

Examination of the use of modified lime sludge as a capping material for waste rock or tailings.

Status:

Large amounts of sludge are generated when lime is used in the treatment of AMD before being released to the environment. This sludge is a liability for two main reasons. There is the potential of the heavy metals in the sludge being leached out and released to the environment. Also, the material is voluminous and requires large storage areas. If the lime sludge can be adequately dewatered, it is possible that the sludge could be incorporated into an engineered cover.

Inorganic materials when used for capping are susceptible to failure in providing water-tight and air-tight capping because of cracking as the rock or tailings pile settles, or because of dessication. In this work, it is proposed that lime sludge be used as a filler in an inexpensive elastomeric material which in turn would be used as a capping cement. An elastomeric cement will be designed which will contain a large proportion of sludge in its matrix. Investigation of the compatibility of the plant sludge with elastomer will be undertaken and sludge modification undertaken if required.

The following tasks are being completed:

- characterization of candidate sludges;
- investigation of compatibility of these sludges with elastomeric material;
- determination of adhesion characteristics of capping material to

typical waste rock; and

- evaluation of the effect of adverse conditions on elastomeric material.

Because of other priorities at Laurentian, the work did not start until late 1992. It is expected to be completed in August 1993.

ACTIVE **MONITORING**

March 1993

Project 4.2.1: Decommissioning Criteria
Budget: $15,000
Sponsor: .....Ontario
$5,000
Homestake Canada.....$5,000
HBM&S.....$5,000
Expenditures: $0
Manager: M. Blanchette, CANMET
Contractor: Jacques Whitford Consulting Engineers

Objective:

The objective of the project is to comprehensively review the established criteria used by Canadian and United States regulatory agencies to assess the performance of a decommissioned, acid mine drainage problem site, thereby providing both government agencies and industry representatives with an overview of the existing regulatory framework.

Status:

The work associated with this project includes a description and summary of all applicable federal, provincial and territorial legislation pertinent to the close-out of acid-producing mine sites. If no specific regulatory requirements are available, representative case histories for the jurisdiction will be described. Pending regulations and stated policies of the regulatory authorities will also be summarized. Closure criteria, under United States federal legislation and for specific American states, will be compiled for comparison.

Currently regulations and guidelines have been compiled for a majority of the provinces. This work is complete on the federal criteria for both Canada and the United States. Preliminary information from the states of Nevada and California have been collected while Colorado, Montana and Idaho still need to be compiled. Information from additional states will only be compiled if time allows, however it is believed that it would add significantly to the project. This project is expected to be completed earlier in 1993.

ACTIVE **MONITORING**

March 1993

Project 4.5 1: Field Methods Manual - Waste Rock
Budget: $100,000
Sponsor: ..... CANMET
$24,000
AECB $10,000
INCO $25,000
Homestake Canada $10,000
Expenditures: $24,000
Manager: M. Blanchette, CANMET
Contractor: SENES Consultants

Objective:
To produce a field methods manual for waste rock sampling techniques through the following phases:

- Phase I: Review and document all present and applicable sampling methods; and
- Phase II: Assess methods, recommend the key technique(s) and present the methods in a user's manual format.

Status:

Before measures can be implemented to assess and/or reduce the generation of acid mine drainage, pertinent technical information on the waste rock must be gathered. The methods manual will not be restricted to rock sample examination alone but will include the sampling of bacteria, water profiles and physical properties such as bulk density and ice retention.

1992: The scope of work was split into two phases to address concerns voiced by the MEND Management committee and to facilitate funding. Phase I was contracted and completed during this time. The review provides guidance to a broad spectrum of concerned parties as to the available sampling techniques for waste rock and suggested methodologies which may be applied during the various stages of mine development. The goal is to ensure that adequate data are collected during all stages of the mine development such that the database exists to evaluate the acid-generating potential of the waste rock. Parameters including permeability, porosity, moisture content, grain size, flow and infiltration, biological activity, meteorology, and temperature are covered.

1993: The scope of work to address the second phase of this program has been developed, and this work will be initiated in 1993. The proposed work will consist

of the following stages: augmentation of the Phase I review, by assessing the techniques listed according to comfort level, resultant data, estimated cost, and reproducibility; generation of a recommended methods manual to serve as a positional paper at an experts workshop, and a basis for the final report; and finalization of the manual based on the workshop recommendations.

The former stage will be done through a focused survey of the industry, consultants, and regulatory bodies. The final product will be a detailed user's manual of available techniques, with recommendations regarding the most appropriate for given situations.

ACTIVE **MONITORING**

March 1993

Project 4.5.3: ARD Technical Guide Revision - Monitoring Section
Budget: $50,000
Sponsor: ..... CANMET
$50,000
Expenditures: $0
Manager: E. van Huyssteen, CANMET
Contractor: EVS Environment Consultants

Objective:

The objective of the project is to produce a monitoring manual and a complete revision of the monitoring chapter of the Draft B.C. Acid Rock Drainage Technical Guide.

Status:

The B.C. Draft Acid Rock Drainage Technical Guide was completed in 1989. Since that time the B.C. AMD Task Force and MEND monitoring subcommittees have sponsored various literature reviews and monitoring projects to address deficiencies in the guide monitoring chapter. The output of this project will be a monitoring guide to include the following: principles, concepts and restrictions in developing monitoring programs; monitoring technology and equipment installation and maintenance; data management, including QA/QC; and advantages and limitations of the techniques as they are applied to various mining and downstream environments.

A draft outline has been developed and the overall report will be completed by the summer of 1993. The report will begin with a review of acid production, and a discussion of the concepts of pathways and receiving environments. The second section will detail the most important factors which need to be taken into consideration during the development of monitoring programs. These include a statement about the goals of monitoring; defining the expectations of the interested parties; taking into account the background and components of the mine setting; developing a cause/effect model; establishing monitoring objectives; and, developing sample designs. Monitoring by components will then be described. Sufficient useful data management and statistical procedures are to be provided to enable maximum usefulness to be derived from the data generated during monitoring without delving too deeply into theoretical statistics.

Examples of outstanding monitoring programs at selected British Columbia mine sites and their surrounding areas will be outlined. A non-quantitative, fictitious case study, which is essentially a compilation of several real situations, is to be used to illustrate practical aspects of general monitoring programs.

ACTIVE **MONITORING**

March 1993

Project 4.6.1: Assessment of Geophysical Monitoring Methods
Budget: $118,000; 1992/93($83k), 1993/94($35k)
Sponsor: ..... Ontario
$38,000
CANMET $38,000
INCO $54,558
Expenditures: $68,000
Manager: E. Kustan, INCO
Contractor: Inco Exploration & Environmental Control

Objective:

To evaluate the application of four geophysical methods to detect and assess subsurface migration of acid mine drainage.

Status:

For active as well as non-active sites, effective monitoring techniques are needed which are cost-effective. Acid mine drainage is generally much more conductive than natural groundwaters, and this contrast can be used to directly detect AMD remotely by using electrical geophysics developed for resource exploration and engineering applications.

The research, being carried out at two sites in the Sudbury Basin, Levack tailings and Pistol Dam (Copper Cliff tailings), is focusing on the assessment of the following methods :

- ground-based conductivity;
- airborne conductivity surface;
- induced polarization/resistivity survey of sulphide content; and
- "self potential" surveys of sulphide oxidation.

The ground-based conductivity surveys are being carried out at sights where there is well documented information on subsurface contamination, and monitoring instrumentation already in place. In the Levack tailings area alone, a total of 22 new water sampling wells have been established and made available, over and above the four covered under this project.

Surface frequency domain Electromagnetic (EM) test well drilling and downhole

EM surveys have been largely completed at both sites. Airborne EM apparent resistivity maps have been prepared for the entire Sudbury Basin and airborne EM data over the Levack area has been reprocessed to enhance surficial resistivity. In general, preliminary results from the airborne data showed low conductivity backdground ($<$ 10 mS/m)and high conductivity sources ($>$ 1,000 mS/m), the contrast being ideal for locating anomalous conductivity due to groundwater contamination.

ACTIVE **MONITORING**

March 1993

Project 4.6.2: Continuous Monitoring of AMD - Literature Review
Budget: $50,000
Sponsor: .....Québec $47,000
Expenditures: $28,000
Manager: L. Bienvenu, CRM
Contractor: University of Laval

Objective:

To identify and evaluate the capability of commercially available continuous monitoring technologies to meet the monitoring requirements at tailings sites in Canada.

Status:

It is widely recognized among researchers in water quality monitoring that sensitivity to variations and trends is key to a good sampling design. Especially for short-term comparisons, fixed-frequency single samples have severe limitations and may give a distorted reading of overall water quality. The use of continuous monitoring initially and/or during certain periods through the year may be considered appropriate.

The tasks associated with this project include: establishment of the requirements to be used as criteria in evaluating continuous monitoring technologies; review and evaluation of existing technologies based on these criteria; identification of sites for experimental application of continuous monitoring systems; and a summary of all existing technologies and an assessment of their capabilities against the criteria established.

A comprehensive literature review, including Canada, United States and Europe, has identified an extensive list of references regarding continuous monitoring. This list has since been narrowed down to the most applicable. An extensive list of equipment manufacturers, applicable to continuous monitoring, has been generated and information regarding their use, capabilities and limitations is being collected. The majority of manufacturers allow for the continuous monitoring of pH, conductivity, and temperature. It is noted that systems are rarely furnished with the ability to do likewise for specific ions (ie. iron, copper, zinc etc).

The project is expected to be completed by the summer of 1993.

ACTIVE **MONITORING**

March 1993

Project 4.8.1: Monitoring of the Flooded Solbec Pit

Budget: $139,000

Sponsor: ..... CANMET

$ 30,000

Québec.....$130,000

Expenditures: $109,000

Manager: F. Belle-Isle, CRM

Contractor: Serrener Consultation Inc.

Objective:

The objective of the three-year monitoring project is to assess the long-term effects of relocating waste rock into an open pit and subsequently flooding the pit for the control of acid generation.

Status:

The Solbec mine is located in the Eastern Townships in the province of Québec. Acid generation and drainage from waste rock on surface resulted in the contamination of surface water and high concentrations of base metals. In 1988, 276,000 cubic meters of highly oxidized waste rock were placed in the dewatered pit, covered with a 5 cm layer of limestone and reflooded to a water depth of 1.5 m as part of a control measure. Characterization of the pit followed by a detailed monitoring program has been undertaken to better understand the consequences of the chosen method of control on the surrounding environment.

In the first year, the work included: mine site characterization; borehole placement (one upstream, two within the pit and two downstream); piezometer installation in the boreholes (the four latter, multilevel, the former, single level); and chemical analyses of solid and liquid samples from the pit and surrounding areas. The general hydrogeological regime for the site has been prepared using all information available.

Based on the first year results, particularly from the downstream holes, it has been recommended that additional boreholes be placed downstream of the filled and flooded pit to allow more comprehensive monitoring of potential downstream contaminant migration. A geophysical survey was proposed to optimize the placement of these holes. A review of the proposed survey has indicated that the Solbec pit area would be a good site for EM surveys given the resistive host rocks

and the absence of both thick conductive overburden and interference from powerlines. Use of EM-31 and EM-34 coverage downstream and around the periphery of the pit has been recommended. The survey is planned for April 1993.

ACTIVE TECHNOLOGY TRANSFER

March 1993

Project 5.3.1: Laurentian Database
Budget: $35,000
Sponsor: ..... Ontario $35,000
Expenditures: $35,000
Manager: D. Cowan, MNDM Ontario
Contractor: Laurentian University

Objective:

Establish a bilingual database of materials supporting research into the control of acid mine drainage.

Status:

A bilingual database was established as part of Laurentian University's Mining Environment Database. To date there are over 6,000 abstracted references to journal articles, books, government reports and conference proceedings.

The database includes a complete bibliographic description of titles as well as abstracts. In addition, actual documents are available in the Laurentian Library for consultation or for borrowing through interlibrary loan. Access to the Laurentian database is free to anyone with a telephone modem/computer hookup.

A brochure entitled "Mining Environment Database:Abandoned Mines, Acid Mine Drainage & Land Reclamation" has been published.

A central source of information on acid mine drainage now exists and is a benefit to MEND membership as well as others working in this field.

All information received at Laurentian was abstracted and input in the Database during summer period when staff was available through the Environment Youth Corps program.

APPENDIX E

Recommended Projects **March 1993**

Number	Titles:
1.15.2	AMD form Open Pits - Expansion & Verification of Model
1.31.2	Residual Weathering Production Waste Rock Dumps
1.32.2	Pyrite Oxidation - Lithological & Mineralogical Factors
1.41.2	ARD Waste Rock Monitoring Database
1.42.1	Critical Review & Geochemical Modelling
1.43.1	Physical Waste Rock Modelling - Coordination
1.51.1	Quantitative Analysis of Chemical & Biological Kinetics
1.51.2	Nonlinear Modelling for Chemical Kinetics for AMD
2.12.2	Evalulation of Existing Underwater Disposal Sites - 1993 Program
2.15.1	Water covers - Laboratory/Field
2.20.1	Evaluation of Alternate Dry Covers
2.21.2	Engineered Dry Covers for Tailings - Noranda
2.23.2b	TTD - Kidd Creek
2.23.2c	TTD - Tracer Study
2.23.2d	TTD - Geochemical Study
2.25.2	Wood Waste Covers - East Sullivan
2.34.1	Cementitious Covers - Westmin
2.35.2c	Lysimeter Covers for Waste Rock
2.45.1a	Separation of Sulphides
3.13.1b	Small Seeps - Field Evaluation
3.21.3	Removal of Metals - Pilot Tests
3.22.1	AMD - Water Quality Survey
3.32.1	Lime Treatment - Process and Sludges
4.6.3	Remote Monitoring - Techniques Review and Manual
4.8.2	Sediment Sampling Probe Field Application
5.3.2	Expand Databases at Laurentian & UBC
5.6.2	Third International Conference on Abatement of Acidic Drainage
5.7.1	MEND Newsletter
5.8.1	Economic Evaluation of MEND-developed Technology
6.1	New Ideas Solicitation

Project 1.15.2: AMD from Open Pits - Expansion and Verification of the Model
Budget: $150,000 (Phase I $50k, Phase II $100k)
Sponsor: To Be Determined
Manager: To Be Determined
Contractor: Morwijk Enterprises Ltd.

Objective:

This project addresses two primary objectives: expansion, improvement, and verification of the original MINEWALL code from version 1.0 to 2.0 with appropriate user instructions; and the collection of field data at two representative minesites and the subsequent calibration of MINEWALL version 2.0 using this field data.

Fit With Program:

At a minesite, acid drainage and metal leaching can occur in mine openings, waste rock dumps, tailings, and pit mine walls. During decommissioning and closure, long-term collection and treatment of mine water may cost a great deal; and the capability of predicting mine water chemistry may prove valuable for assessing the extent of treatment, prevention and control measures.

A literature review on the physical and geochemical impacts of mines, a short-term field investigation of mine walls at Equity Silver, preliminary development of MINEWALL to simulate and predict physical and geochemical impacts, and the formulation of draft criteria for pit decommissioning have been completed (1.15.1). The first phase of the recommended project will reduce known limitations of the model such as the arbitrary equations describing pit flooding and decreasing sulphide oxidation through time and the inability to explicitly simulate underground mines. Verification will consist of mathematically comparing MINEWALL predictions against known outcomes using simplified data sets.

Towards the second phase, potential sites for the field studies have been listed and ranked according to the current level of relevant data known to exist at the sites. Two sites will be considered and the maximum sampling and modelling effort per site is estimated to be $50k and would be completed within one year. Use of mining company in-house sampling and analytical services, however, may reduce costs.

Projected Output:

The results of this study will generate a detailed user's manual with explanations of procedures for input, editing, and output, as well as instructions for collecting field data and calibrating MINEWALL version 2.0 to field data. A detailed report will contain all field studies of mine walls carried out in this and previous studies, and appendices containing all data will be included.

RECOMMENDEDPREDICTION - Basic Research
March 1993

Project 1.31.2 Residual Weathering Products in Waste Rock Dumps
Budget: $40,000
Sponsor: British Columbia
$20,000
Placer Dome $10,000
Manager: W. Price, B.C. MEMPR
Contractor: University of British Columbia

Objective:

The objectives of this project are to:

- determine the composition of residual weathering products retained in waste rock dumps; as well as
- measure the amounts and assess the long term stability of these weathering products.

Fit With Program:

Investigations into the physical and chemical fate of residual weathering products within waste rock dumps are important factors in the development of a predictive chemical evaluation scheme. Investigations will be carried out at a selected site in western Canada.

Through this recommended project, information on the lithology, mineralogy and weathering characteristics of the rock will be compiled. Analyses of the seepage at the site will be made. Similar research available from other sites will be reviewed as will the methods available for analyzing secondary weathering products. Samples will be collected from any existing cuts in the waste rock dumps (roads, rehandled rock, etc.) and from shallow trenches constructed on the tops, sides, and at the base of the waste rock dumps. The composition of the weathering products will be determined using a variety of analyses including x-ray diffraction, electron microscopy, and selected dissolution techniques. Adsorption, equilibrium and kinetic models will then be used to assess and analyze the collected data.

Projected Output:

The final report for this project will be in the form of a M. Sc. thesis for the Department of Soil Science at the University of British Columbia. The report will discuss the possible genesis of weathering products, the present geochemical processes, and will predict the long-term geochemical stability of the dumps.

RECOMMENDEDPREDICTION - Basic Research
March 1993

Project 1.32.2: Pyrite Oxidation - Lithological and Mineralogical Approach
Budget: $40,000
Sponsor: British Columbia
$20,000
Placer Dome $10,000
Manager: W. Price, B.C. MEMPR
Contractor: University of British Columbia

Objective:

To investigate the effect of lithological and mineralogical factors on differences in the availability and reactivity of acid-generating or potentially acid-generating sulphide minerals.

Fit With Program:

Determining the relative oxidation rates of individual sulphide species is a basic and key prediction component. To date most of the research on sulphide oxidation in waste rock dumps has focused on either: the effect of environmental factors such as temperature, oxygen transfer, moisture movement, and bacterial activity; or the qualities and relative proportion of acid-generating and acid consuming minerals. In the past, lithological and mineralogical factors may have been largely overlooked (see project 1.32.1), although they likely play significant roles in determining the oxidation rate.

Data on the rates of pyrite weathering will be compiled for different rock types both in the field and in the laboratory. Rock types will be selected which have similar acid generation potentials but with observed differences in oxidation rates. Availability of weathered and unweathered material must be considered for characterization which will include: surface exposure to pyrite; permeability and therefore internal exposure of pyrite; presence of other easily weatherable or deformed minerals; and distribution of pyrite versus other sources of acidity and alkalinity. Pyrite grains will also be characterized using microscopie and microprobe analyses for, among others, type and degree of crystal development, physical deformation (fractures), and surface and internal chemical composition. The oxidation of different pyrite types will be simulated using laboratory weathering techniques.

Projected Output:

A report, in the form of an M.Sc. thesis for the Department of Mining and Metallurgy at the University of British Columbia, will correlate observed differences in rock and pyrite properties with differences in the reactivity of the sulphide minerals. This work is expected to compliment the observations of project 1.32.1.

RECOMMENDEDPREDICTION - Modelling
March 1993

Project 1.41.2: ARD Waste Rock Monitoring Database
Budget: $20,000
Sponsor: ..... CANMET
$20,000
Manager: To be determined
Contractor: University of British Columbia

Objective:

To provide an overview of all ongoing and previous field studies of acid rock drainage in waste rock. The overview will describe the biogeoclimatic condition, the characteristics of the waste rock, information about the research/monitoring methods, a summary of any conclusions that have been drawn from this information, and the availability of the associated data.

Fit With Program:

At the International Workshop on Waste Rock Modelling held in late 1992 (1.41.1), it was recommended that a listing of comprehensively monitored waste rock dumps be generated. The resulting database would be used to identify field information available for calibrating and verifying ARD modelling and prediction research. Waste rock dump instrumentation and monitoring is costly, therefore duplication should be avoided, and the best use made of available information, and future monitoring programs.

Appropriate hardware and software must be selected to ensure easy accessibility. Information will be collected from all relevant sources, including the Laurentian University database, provincial and federal authorities, operating mining companies and a review of the literature. Representatives from Australia, Sweden, Norway, and the United States who attended the workshop will also be contacted.

For each applicable site the following information will be requested: biogeoclimatic conditions of the minesite and surroundings; characteristics of the waste rock (lithology, mineralogy, particle size etc.); the parameters measured and the associated methods used; the number and frequency of sampling; the contacts for the research/monitoring program; and the availability of the data and an applicable contact. The database is not being developed to contain monitoring data itself, but to give a detailed listing of what data is available and where it may be obtained.

Projected Output:

This project will result in a database, to reside at the University of British Columbia, which can be accessed through the Internet system. A report will describe the database, its operation, and will tabulate the information collected.

RECOMMENDEDPREDICTION - Modelling
March 1993

Project 1.42.1: Critical Review of Geochemical Modelling
Budget: $40,000
Sponsor: ..... CANMET
$20,000
Ontario $20,000
Manager: To Be Determined
Contractor: By competitive Bid

Objective:

The objectives of the proposed work are to: identify the various geochemical processes occurring in waste rock piles at all stages of acid generation; and list and thoroughly review existing geochemical models which are being used, or can be adapted, for predicting metal species and their concentrations in waste rock piles.

Fit With Program:

Within the overall program, the Prediction committee is proposing to develop a model or models to predict acid drainage in waste mine rock, possibly with international participation (Sweden, Norway, Australia, and the United States have expressed interest in a joint international program). Through an international workshop (1.41.1), the concept of waste rock modelling was reviewed and it was concluded that while considerable progress has been made in understanding oxygen and heat transport, predicting the geochemical transport of metals in waste rock piles still remains a major challenge. This two phased project will address a go/no go decision in such model development.

Phase one is proposed to list and review controlling geochemical processes and input parameters for predicting species concentrations in waste rock piles.

Phase two will list and thoroughly review geochemical models (from published and unpublished literature and all other relevant sources) that can be used for predicting processes and seepage quality in waste rock piles. The review shall include an outline of their pertinent features, utilities, strengths and deficiencies, previous applications and computing hardware requirements. The names of the developers and information on the cost and source of acquisition are also to be provided.

Projected Output:

The report shall list and critically describe existing models that can be used directly or adapted to predict the geochemical behaviour and transport of metals and other chemical species in waste rock. The report will outline and recommend any additional laboratory and field work required to augment existing information so that geochemistry can be incorporated into waste rock modelling efforts.

March 1993

Project 1.43.1: Physical Waste Rock Modelling - Coordination
Budget: $70,000
Sponsor: To Be Determined
Manager: To Be Determined
Contractor: By Competitive Bid

Objective:

The objective is to develop a work plan for physical modelling of acidic drainage in waste rock, propose a budget, and identify, and where possible, establish a research team to develop mathematical models to address physical transport. The plan would detail work required to describe and predict oxygen, heat, solute and water transportation in waste rock piles.

Fit With Program:

As an initial phase in the program to predict acidic drainage from waste rock, a comprehensive program must be put in place for the development of models for predicting oxygen, heat, solute and water transportation in waste rock piles. As identified at the International Workshop on Waste Rock Modelling (1.41.1), initial mathematical simulations would be limited to the physical parameters before a good understanding of the capabilities associated with geochemical process simulation can be obtained (1.42.1).

The modelling requirements or needs associated with predictive modelling are to be outlined. Expertise, Canadian and possibly international, is to be identified, and a research team to address the modelling requirements specifically defined.

The anticipated modelling program shall consider all stages of acid generation (from new mines to existing mines which are already generating acid or have not yet generated acid). It shall be confined to the development of the physical model(s) only. At this stage geochemical modelling will be pursued separately. The program shall also clearly outline and describe any anticipated laboratory and field work complementary to both the physical and geochemical modelling efforts.

Projected Output:

A report will be submitted which describes the requirements for developing models that can be used to predict oxygen, heat, solute and water transport in waste rock

piles. The required tasks will be outlined and a listing made of carefully selected Canadian and international experts who would constitute the research team. The report will present a detailed modelling program, showing the roles and anticipated contributions of the various research team players in the modelling effort and the associated time frame and budget.

RECOMMENDEDPREDICTION - New Ideas
March 1993

Project 1.51.1 Quantitative Analyses of Chemical and Biological Kinetics
Budget: $12,000
Sponsor: Environment Canada
$11,750
Manager: B. Godin, Environment Canada
Contractor: M. Otwinowski, Synergetic Technology

Objective:

The purpose of the project is to provide quantitative analysis of the interrelated elementary chemical, biological and physical processes which together are responsible for acid mine drainage.

Fit With Program:

The emphasis in predicting the quantity and rate of acid mine drainage generation is being placed, to a large extent, on mathematical modelling. The issue of linear versus non-linear chaotic behaviour is considered through this "new ideas" project.

This study will concentrate on the quantitative analyses of acid formation and energy generation during pyrite oxidation. The quantitative analysis will be performed for elementary chemical reactions including bacterial oxidation and neutralization by alkaline compounds with the rates dependant on temperature variation.

Using analytical and already existing standard numerical methods, a search for possible limit cycles, quasi-periodic and chaotic behaviour will be performed. If chaotic behaviour is detected, the basins of attraction will be determined both in the space of initial conditions and for values of parameters controlling the reaction rates.

Projected Output:

Quantitative results of this project will provide a hierarchy of importance of elementary processes responsible for acidic drainage. Preliminary sensitivity analysis performed during the project will lead to a better understanding of the nature of interplay between the elementary processes. Quantitative data useful for further modelling by means of partial differential equations encompassing mass and energy transport and spatially nonhomogeneous concentrations of chemical species

and temperature will be provided.

RECOMMENDEDPREDICTION - New Ideas
March 1993

Project 1.51.2: Nonlinear Modelling of Chemical Kinetics for Acid Mine Drainage
Budget: $30,000
Sponsor: Environment Canada
$34,550
Manager: B. Godin, Environment Canada
Contractor: University of Alberta

Objective:

To provide an in-depth study of the basic reactions in the acid mine drainage problem through derivation of the constituent differential equations and application of modern analytical and numerical techniques to investigate the boundaries of chaotic and regular regions in the phase space.

Fit With Program:

The long-term prediction of acid mine drainage must ultimately be based on mathematical modelling. With this in mind it is noted that several theoretical discoveries have revolutionized scientific thinking with regard to mathematical simulation in the past two decades. These are solitons, fractals, limit cycles, and chaos. The latter three concepts have already started making profound impact in the field of chemical kinetics.

The emphasis in this study, which comes under the heading of "new ideas" within the prediction program, will be to examine potential nonlinear or chaotic behaviour of the kinetics of oxygenation. So far rather simplified modelling techniques have been used in the analysis of these complex reactions that possess feedback loops characteristic of chemical chaos systems. Chemical, geological, physical, and microbiological factors will be considered.

The short-term objective will be to study the chemical reactions involved, ie. type, activation energy, rate and thermodynamics. Realistic models of the kinetic reaction equations will then be developed which fully account for the presence of nonlinearity in the form of feedback loops.

Projected Output:

An analysis of the boundaries for chaotic and regular regions in the phase space will result in the determination of predictable and unpredictable ranges of behaviour.

RECOMMENDEDP&C - Underwater Disposal
March 1993

Project 2.12.2:	Evaluation of Existing Underwater Disposal Sites - 1993 Program	
Budget:	$300,000	
Sponsors:	Placer	Dome
	.....	$50,000
	HBM&S.....	(?)
Manager:	J. Robertson, Placer Dome	
Contractor:	To be determined	

Objective:

The objective of the 1993 Subaqueous Disposal Program is to address the recommendations contained in the Peer Review report.

Fit with Program:

At the suggestion of the MEND Board of Directors, a scientific and technical review of all aspects of work conducted to date was completed (Project 2.11.1d). The report identified key areas that are lacking in information. A special orientation session to fully describe the progress and potential of subaqueous disposal to provincial and federal regulatory personnel, held in Winnipeg in October 1992 has provided positive feedback on the merits of the subaqueous disposal method. Additional research work is needed to provide the information needed to support the application of this method.

In order to effectively use the wide range of resources available, to achieve maximum credibility in the future work, and to accelerate the progress of the research, a planning team of technical/scientific experts met in January 1993, to outline a study program for the next 3 to 4 years which incorporated the recommendations made in the review and a specifically focused application scenario. The projects planned for 1993 and later include:

- a literature review on metal toxicology;
- a Paleolimnology Review of the data from Buttle Lake;
- metal flux determinations at Buttle Lake (on a seasonal basis); and
- metal flux determinations / Sediment transport modelling at Anderson Lake (3 sampling campaigns are planned for 1993).

Projected Output:

The major thrust of the measurement program at Buttle and Anderson is to obtain a clear understanding of the reactivity of the tailings sediments with the water column. The original concepts of significantly reduced reactivity of sulphide materials under water must be verified by sophisticated geochemistry work. Additional work is needed and some is planned in 1993 to develop a more complete understanding of the sites under study.

RECOMMENDEDP&C - Wet Barriers
March 1993

Project 2.15.1:	A Study on Water Covers for the Decommissioning of Mine Waste Disposal Sites
Budget:	$487,000
Sponsors:	Noranda Technology Centre $228,000
	Request for funding distributed (for CANMET portion)
Manager:	To be determined
Contractors:	Noranda Technology Centre
	CANMET

Objective:

The proposed study is aimed at using laboratory, numerical, and field methods for evaluating the effect of different depths of water cover (with or without an attenuation layer over the tailings surface) on the long term quality of the overlying and interstitial water.

Fit with Program:

The development of a wet barrier consisting of a shallow layer of water has shown promise in eliminating or restricting sulphide oxidation. Depending on the site specific conditions of topography, hydrogeology, seismicity etc., an economically attractive decommissioning option is possible.

Prior to full-scale testing, laboratory studies will be conducted on both oxidized and unoxidized mine wastes. The study includes measurement and analyses of effective diffusion coefficients and fluxes of selected metals and major ions from oxidized tailings, and evaluation of mineral dissolution from oxidized and unoxidized tailings. Field characterization of site-specific geotechnical and hydrogeochemical parameters will also be done as well as the laboratory measurement of oxygen diffusion fluxes through water covers of different thicknesses, of sediment erosion processes, and of oxidation kinetics and rate of reaction products migration via surface and groundwater flow regimes.

The program will be conducted jointly by Noranda Technology Centre (NTC) and CANMET (Elliot Lake). Total budgeted effort is $487,000 over a two-year period. NTC will be studying the diffusion coefficients and fluxes, and carrying out some field tests. The Noranda portion of the project is fully funded by the company ($228,000). CANMET will be studying the oxygen diffusion characteristics, the wave action and sediment erosion characteristics and contaminant transport flux

measurements. Funds are presently being sought for the CANMET portion of the project.

Projected Output:
The final output from this project will be an in-depth evaluation of water cover on reactive tailings and waste rock, and a laboratory testing procedures manual for the flooding of tailings disposal option. This work will form the background of a design document for shallow water cover design.

RECOMMENDEDP&C - Dry Barriers
March 1993

Project 2.20.1:	Evaluation of Alternate Dry Covers for the Prevention of Acid Mine Drainage from Tailings
Budget:	$50,000
Sponsors:	Lac Minerals $5,000
Manager:	To be determined
Contractors:	Competitive bidding

Objective:

The objective of this study is to prepare a ranking of the potential alternate cover materials that could be considered in the prevention and control of acid mine drainage.

Fit with Program:

One of the primary methods of preventing acid mine drainage from tailings is the placement of a cover which reduces the amount of oxygen and/or water that contacts the acid-generating sulphides. Various soil and clay composite covers, membrane and organic covers are currently being evaluated. While these covers do reduce the oxygen and water entering the tailings, they are generally too expensive, too short term or appropriate materials are not readily available. This project will document potential alternatives from literature sources and personal contacts, outline possible methods of application and the pro's and con's of each. The alternatives will be ranked according to potential for success and relative cost. This project will assist the MEND Prevention and Control committee select the best alternatives for which laboratory and field test programs can be developed.

This project was not identified in the Revised Research Plan but it is considered to be a critical study for the dry barriers area. The project is directed towards finding affordable solutions to acid mine drainage which is Priority I for MEND.

Projected Outputs:

The projected outputs from this project will include a list of the potential alternate cover materials with ranking of the potential for technical and economic success. Recommendations of research needs not currently being followed will also be included.

RECOMMENDEDP&C - Dry Barriers
March 1992

Project 2.21.2:	Engineered Dry Covers for Tailings - Noranda
Budget:	$348,000 to $469,000 (increase in scope)
Sponsors:	
$62,800	Noranda
	CANMET $25,000
	Québec..... $24,100
Manager:	E. Yanful, Noranda Technology Centre
Contractors:	Noranda Technology Centre
	McGill University

Objective:

The objective of this increase in scope for the engineered dry covers project at Waite Amulet is to provide additional monitoring equipment for modelling purposes and to evaluate the effect of cyclic freeze/thaw on the cover materials. A wind erosion protection layer has been added to the piles as well as a fence to protect the area from vandalism.

Fit with Program:

The design, construction and instrumentation of the test plots was completed by the fall of 1990. The four fiels test plot covers are comprised as follows: 2 composites of fine-grained soil layer underlain and overlain by coarse-grained layers; a composite of a geomembrane (HDPE) underlain and overlain by coarse-grained soil layers and one control plot. This is a Priority I project in the Revised Research Plan.

Wind erosion at the site was observed to be quite substantial and has resulted in a loss of about 80 mm (after the first 10 months) in the total thickness of the upper sand layer. Field observations have shown that the presence of the upper sand layer is critical to the satisfactory performance of the underlying clay layer and therefore a 100 mm gravel layer was placed on top of each of the 3 covered test piles to stop wind erosion. Vandalism to field equipment has required the construction of a fence around the test plots.

The monitoring program was expanded to include precipitation and pan evaporation measurements to provide data for hydrologic modelling using the computer program HELP. Freezing and thawing is considered to be a major problem area for soil covers. A contract to study the cyclic freeze/thaw effects on the oxygen diffusion through the clay cover, on the water drainage characteristics

of the clay cover and on the compatibility of the membrane cover was proposed and accepted.

Projected Output:

An evaluation of the effectiveness of full scale engineering soil covers in the abatement of acidic drainage from tailings impoundments will be produced. The data will confirm the laboratory results used to design the full scale covers (Project 2.21.1).

RECOMMENDEDP&C - **Others**
March 1993

Project 2.23.2b: Hydrogeological and Geochemical Analyses of the Thickened Tailings Disposal (TTD) System at Kidd Creek Mines
Budget: $88,700
Sponsor: ..... Falconbridge $88,700
Manager: D. Bordin, Falconbridge Limited (Kidd Creek Division)
Contractor: Noranda Technology Centre

Objectives:

The objectives of this study are to conduct additional hydrological measurements and modelling, water quality sampling and analyses, and hydrological experiments under controlled laboratory conditions as recommended in Project 2.23.2a.

Fit with Program:

In contrast to most conventional tailings ponds, tailings disposal by the thickened, sloped, discharge system results in a gently sloping deposit of tailings without a slimes pond and without high perimeter dams. The literature indicates that thickened tailings disposal provides a homogeneous tailings mixture which exhibits moisture retention characteristics and low hydraulic conductivities that aid in the abatement of acid generation.

Noranda Technology Centre carried out a field evaluation of the site hydrology to obtain a verification of the high moisture retention of the Tickened Tailings Disposal deposit (Project 2.23.2a). In the second year, it was recommended that the contractor:

- continue the measurements of the water balance components to develop a monthly water budget (emphasize measurements of snowmelt, runoff and tailings discharge);
- measure the effects of discharge water on total infiltration, and predict the response of the water table to discontinued discharge;
- revise the hydrologic budget modelling based on new information; and
- conduct laboratory experiments to measure evaporation and infiltration rates under controlled conditions.

Projected Output:

The information would be included in a synopsis report that would assess the effectiveness of the thickened tailings disposal option in reducing acidification potential.

RECOMMENDEDP&C - **Others**
March 1993

Project 2.23.2c: A Tracer Study of Fluid and Contaminant Movement in the Upper Surface of the Thickened Tailings Disposal (TTD) System at Kidd Creek Mines

Budget: $78,200

Sponsors: ..... Falconbridge $39,100

Ontario $20,000

CANMET $20,000

Manager: D. Bordin, Falconbridge Limited (Kidd Creek Division)

Contractor: E.I. Robinski Associates Ltd.

University of Saskatchewan

Objectives:

The objectives of this study are to verify modelling results of the behaviour of thickened tailings disposal against field observations.

Fit with Program:

In contrast to most conventional tailings ponds, tailings disposal by the thickened, sloped, discharge system results in a gently sloping deposit of tailings without a slimes pond and without high perimeter dams. The literature indicates that thickened tailings disposal provides a homogeneous tailings mixture which exhibits moisture retention characteristics and low hydraulic conductivities that aid in the abatement of acid generation.

Three aspects of the hydrological behaviour of thickened tailings need to be evaluated: the net infiltration due to climatic flux; the pathway and rate of migration of infiltrating water; and the role played by the zone of capillary saturation attenuating infiltration and chemical transport. The field monitoring would be carried out over two seasons. These results would then be used in the third year to calibrate numerical models of the performance of the thickened tailings disposal method with respect to seepage and contaminant transport.

Projected Output:

An evaluation of the ability of the thickened sloped tailings disposal method to reduce the amount of acid generation, both during operation and after closeout of

the area, will allow Falconbridge to define more precisely the treatment requirements for decommissioning. This study would produce a technical method for direct field measurement of the hydraulic behaviour of tailings with respect to rates of infiltration and chemical transport. Such a methodology could be applied on other tailings sites to evaluate potential contaminant rates.

The information would be included in a synopsis report that would assess the effectiveness of the thickened tailings disposal option.

RECOMMENDEDP&C - **Others**
March 1993

Project 2.23.2d: (TTD)	Geochemical Evaluation of the Thickened Tailings Disposal System at Kidd Creek Mines
Budget:	$250,000
Sponsors:	
$125,000	Falconbridge
	Ontario $ 63,000
	CANMET $ 63,000
Manager:	D. Bordin, Falconbridge Limited (Kidd Creek Division)
Contractor:	University of Waterloo
	CANMET

Objectives:

The objectives of this study are to determine the geochemistry of the tailings cone through the pore water chemistry and the control mechanisms as well as a whole rock study of the cone solids.

Fit with Program:

In contrast to most conventional tailings ponds, tailings disposal by the thickened, sloped, discharge system results in a gently sloping deposit of tailings without a slimes pond and without high perimeter dams. The literature indicates that thickened tailings disposal provides a homogeneous tailings mixture which exhibits moisture retention characteristics and low hydraulic conductivities that aid in the abatement of acid generation.

The piezometers completed in Phase a will allow complete definition of the water table within the cone and detailed determination of the porewater geochemistry from the tailings surface through the body of the cone and into the underlying glacial till. As well as obtaining data on the porewater chemistry of the cone, the pore gas oxygen, sulphur-oxide and carbon dioxide contents will be measured in the vadose zone via field instrumentation. Continuous core samples through the cone were obtained during the installation of the piezometer stations and these will be used for detailed mineralogical work, as well as for a complete determination of the "whole rock" chemistry of the cone. The pore liquid geochemistry of the cone will be interpreted by the computer codes PHREEQE and MINTEQA2 and compared to the results of the mineralogical and chemical analyses. This combined geochemical and mineralogical study should more conclusively define the mechanisms controlling the concentrations of dissolved constituents in the tailings.

Projected Output:

The information would be included in a synopsis report that would assess the effectiveness of the thickened tailings disposal option.

RECOMMENDEDP&C - Dry Barriers
March 1993

Project 2.25.2:	Design of an Organic Barrier Using Wood Waste - East Sullivan
Budget:	$431,000 (Year 1 - $142,354)
Sponsor:	Québec.....$351,000
Manager:	A. Paquet, Centre de recherches minérales
Contractors:	Roche Environmental Ltd.

Objective:

The objective of this study is to evaluate the effect of forestry by-products such as wood waste on the process of sulphide tailings acidification and the effect of these various organic amendments on the quality of the surface and groundwater at the East Sullivan tailings dump in northwestern Québec.

Fit with Program:

One of the primary methods of preventing acid mine drainage from tailings is the placement of a cover which reduces the amount of oxygen and/or water that accesses the acid-generating sulphides. Various soil and clay composite covers and membrane covers are currently being evaluated.

MEND has also started evaluations of a number of organic covers which may function to limit oxygen penetration but not water penetration. It is perceived that the organic materials will create a strongly reducing layer due to the continued biological degradation of the organics and other processes. These covers may require the intermittent addition of new organic material to maintain the oxygen scavenging capability. Covers composed of forest waste or other organic wastes will be useful for the mining industry only if they provide a permanent, socially-acceptable and cost-effective solution to tailings management.

Three separate elements have been defined for this project. The first two are construction (Year 1) and monitoring of the field plots. The third element is a more generic evaluation of how organic layers function leading to an understanding of what criteria are important, how they can be improved and other materials that might be considered.

This Priority I and II project is an important component of the development of dry barriers technology.

Projected Output:

The deliverables includes a report containing the results from an experimental field evaluation to assess whether the wood waste cover layers function as predicted. The analyses for harmful contaminants from the tailings leachates and the biological activity (biodegradation and 202acteriology) will also be included.

RECOMMENDEDP&C - Waste Rock
March 1993

Project 2.34.1 Use of Cementitious Covers to Control Acid Generation at Westmin's HW Mine - Shotcrete Field Trial

Budget: $130,000

Sponsors: ..... Westmin $100,000

CANMET ..... $ 30,000

Manager: R. van Dyk, Westmin

Contractor: Northwest Geochem

Objective:

The objective of this program is to demonstrate the long-term effectiveness of a large-scale shotcreted cementitious cover as a means of reducing acid production in waste rock dumps. In addition, the test provides an opportunity to develop better automated techniques for large-scale application of the shotcrete concrete cover material.

Fit with Program:

The evaluation of cementitious covers for waste rock piles has been identified as a priority item in the Revised Research Plan by the P&C committee for the prevention and control of acidic drainage. It has been recognized that large-scale field trials should be conducted to obtain more data on the long-term effectiveness of the cementitious covers. This project meets the MEND Plan requirements by assessing the cover's capability of reducing AMD on the waste rock piles and by evaluating the cover in terms of durability and practicability on a large-scale application.

Previous studies completed at the Westmin site have shown that on the basis of laboratory tests and limited field studies, the approach of using cementitious materials as a cover and grouting medium appears to be viable and cost effective, and that further investigation of field application techniques should be pursued. This project is a follow-on project which developed from the recommendations made by the contractor in the previous study. Specific tasks in this project include: (1) determining ways of reducing large-scale application costs through increased production and more automated equipment; (2) testing the effectiveness of shotcrete cementitious mixtures in reducing infiltration into the waste rock piles; and (3) evaluating the effect of the cover placement in a large-scale application.

Projected Output:

An evaluation will be completed on the effectiveness of cementitious covers for the abatement of acidic drainage on waste rock.

RECOMMENDEDP&C - Waste Rock
March 1993

Project 2.35.2c: Lysimeter Evaluations of Cover Alternatives - Noranda
Budget: $145,000 to $195 000 (increase in scope)
Sponsor: Noranda Technology Centre $18,000
Québec..... $32,000
Manager: E. Yanful, Noranda Technology Centre
Contractor: McGill University

Objective:

The objective of this increase in scope for the lysimeter evaluations of cover alternatives project is for additional modelling of geochemical processes associated with the different measures being investigated.

Fit with Program:

The experiments were started in June 1991 and weekly monitoring of the drainage water through the lysimeters have been in progress since then. The techniques investigated are water cover, soil cover, wood bark cover, and addition of limestone and phosphate rock (apatite). Potentially acid-generating waste rock samples used in the investigation were obtained from the Stratmat mine in New Brunswick and from a Québec-based mine. The investigation involved outdoor lysimeter tests and indoor laboratory column experiments.

Aqueous geochemical modelling of the effluents was completed in Stage 1 of this project. The geochemical stage was designed to evaluate efficiency and suitability of different treatment techniques using the available fluid-rock interaction computer code. During the first stage, preliminary speciation models were developed for each of the experiments and geochemical predictions were made. The latter in turn provided information about the potential efficiency of the treatment in inhibiting the release of metals into the effluent.

The objective of this stage is to develop comprehensive models (using the EQ3 computer program) for each of the experiments that will build on the experiences gained in the preliminary exercises. Realistic predictions of the efficiency of each of the treatment measures can now be expected with the proposed procedures and the longer sampling period.

This Priority II project is an important component of the development of wet and

dry covers for waste rock.

Projected Output:

A performance report describing the relative effectiveness of the various techniques, including modelling, will result from this work. This report will aid in the selection of prevention and control strategies for waste rock disposal.

RECOMMENDEDP&C - **Others**
March 1993

Project 2.45.1a:	Separation of Sulphides from Mill Tailings, Phase a
Budget:	$50,000 to $75,000 (Phase a)
Sponsors:	
$20,000	CANMET
	Ontario $20,000
Manager:	G. Hope, Lac Minerals
Contractors:	Competitive bidding

Objectives:

The objectives of this project are to: evaluate various conventional mineral processing technologies that could be applied to the separation of sulphides in tailings; evaluate the relationship between sulphide elimination and acid generation; and evaluate the operating costs of various separation options.

Fit with Program:

The start of acid generation in tailings is due to the bacteria catalyzed oxidation of the contained sulphides. Most of the acid drainage work to date has looked at the elimination of water and/or oxygen from the tailings, both of which are required to oxidize the sulphides. This project will look at the removal of the sulphides so that the sulphide portion can be treated separately and the non-sulphide portion can be disposed of by conventional sub-aerial techniques. It is also considered that this low-sulphide product may be part of a cover over existing tailings.

A two-phase project is proposed in which Phase a would be the bench scale testing (mineral processing tests on characterized tailings samples) and evaluation (costs and effectiveness of various techniques) and Phase b, assuming success in Phase a, would involve on-site pilot or full-scale testing of selected technologies.

Pre-separation as a method to control AMD is a Priority I area in the MEND Revised Research Plan.

Projected Output:

If the sulphides can be separated from the non-sulphides, this opens up several disposal options. Since the sulphide portion will have a significantly reduced volume, separate underwater disposal in a lined containment may become realistic.

Various techniques which could be used during mine development and operation will be evaluated and methods manuals for application of these techniques will be produced.

RECOMMENDED **TREATMENT**
March 1993

Project 3.13.1b: Passive Treatment of Small Seeps
Budget: $60,000
Sponsors: To be determined
Manager: To be determined
Contractor: Competitive bidding

Objective:

To demonstrate the applicability of passive, low-cost processes for treating small volume seepages of acidic drainage.

Fit With Program:

Passive treatment processes are under development in Canada and the United States and these include anoxic limestone trenches, lime organic beds, biotrenches, and biobeads. The ARUM process (Project 3.11.1) although shown to be effective at small flows, may need frequent care and attention. An engineered wetland at Bell Copper in British Columbia has been shown to be effective in removing copper, but the stream contains only low concentrations of oxidation products.

Bench scale tests on passive treatment systems has been completed at Noranda Technology Centre, (Project 3.13.1a). Three of four methods evaluated have shown promise and the Treatment committee is evaluating the results before considering initiating field tests. The Heath Steele mine site in northern New Brunswick is believed to be an ideal field site for evaluating the application of these methods to treat small or "nuisance" seeps. There exists at the site several small seeps that result from mining activity, use of sulphide wastes in construction and undisturbed seeps from rock fissures.

This project fits precisely with the Priority I component of the Revised Research Plan - "Treatment of Small Seeps". The estimated costs in 1993 are $60,000 for field installations. Monitoring of field performance will be done over 2 years, and is estimated to cost $60,000.

Projected Outputs:

The laboratory and field results from this project are critical components of a design book for the collection and treatment of small seeps that will be produced in 1995.

Project 3.21.3: Removal of Metals from AMD - Pilot Tests
Budget: $65,000 (1993)
Sponsors: To be determined
Manager: To be determined
Contractor: Competitive bidding

Objectives:

Demonstrate on a small pilot scale the applicability of either ion exchange or chemical methods for removal of selected metals from acidic drainage. The metals removal process will significantly lower the metal content of subsequent treatment sludges.

Fit With Program:

Two laboratory-scale projects on the removal of metals from acidic drainage before lime neutralization are nearing completion. As outlined in the Revised Research Plan, either the ion exchange or the selective precipitation method will be tested on a small pilot scale.

Removal of metals from acidic drainage effluents would allow treatment plant operators to generate treatment products which do not pose in the long term the risk of generating a toxic effluent. This would provide the walk-away closure scenario when acidic drainage is effectively stopped, and the lime treatment is shut off. Little to no care and maintenance of treatment sludge ponds would be required if the sludge has low heavy metal content. "Walkaway" at minimum cost is the property owner's prime closure objective.

The laboratory tests will be carefully reviewed before pilot scale tests are initiated. Economics and range of applicability will be significant factors in the decision. If the decision is negative with respect to continuing the project, the budget resources will be switched to sludge and treatment products stabilization.

This project will not start until the third quarter of 1993, when the evaluation of the alternative technologies is complete and the survey on acid mine drainage characteristics (Project 3.22.1) is completed. Projected costs for 1993 are $65,000, and for 1994 $65,000 to $85,000.

Outputs:

This project will result in description and recommendations of the design and operation of a process to remove metals from acid mine drainage. Actual commercialization of the process will cost much more and will be done outside of MEND.

RECOMMENDED **TREATMENT**
March 1993

Project 3.22.1: Canada-wide Survey of Acid Mine Drainage Characteristics
Budget: $11,500
Sponsor: To be determined
Manager: To be determined
Contractor: CANMET

Objective:

The prime objective is to create a data bank on the composition, flowrates and seasonal fluctuation of acid mine drainage streams in Canada. This information will be made widely available and will be used to define strategies in improving acidic drainage treatment techniques.

Fit With Program:

Acidic effluent generation from sulphide tailings and waste rock piles will continue long after cessation of mining activities, posing a long-term liability. Lime neutralization is a common treatment practise to neutralize acid and precipitate heavy metals. This methodology is simple and economically attractive, but it produces large volumes of potentially troublesome sludge, may have high maintenance requirements and may not meet new standards for waste disposal. To improve or replace lime neutralization, new technology applicable to specific sites may be necessary.

In 1991, a report was produced for MEND on the technology options available for removing metals from acidic drainage, and this report provided some basic information on acidic mineral drainage streams in Canada. This information, although limited, demonstrated the wide range of contaminants in various effluents. Although research on the removal of metals from acid mine drainage is currently underway with chemical and ion exchange methodology, it is apparent that a wider database of information on acid drainage characteristics is necessary.

Projected Outputs:

The deliverables will include information in computer-readable and hard copy format on:

a) chemical composition
b) flowrates, sources (e.g., waste rock, tailings seepage, and sample

locations)

c) suspended solids content; and

d) seasonal variation in chemical composition, flowrates and suspended solids content.

RECOMMENDED **TREATMENT**
March 1993

Project 3.32.1 Lime Treatment - Process Review and Sludge Stabilization
Budget: $60,000
Sponsor: ..... Ontario
$30,000
CANMET $30,000
Manager: To be determined
Contractor: Competitive bidding

Objectives:

Review the state-of-the-art and engineering in the chemical (lime) treatment system for all types of acidic drainage encountered in Canada and prepare a reference manual for users. Make recommendations on conducting targeted research and development on the lime treatment system that may be needed.

Investigate methods of stabilization and fixation of lime treatment sludges produced from the neutralization of acidic drainage. Review the background work by others, the range of characteristics found in the field, and make recommendations for laboratory and bench scale tests if needed.

Fit With Program:
Considerable research and process development has been done in Canada and around the world on lime treatment and sludge densification.

Lime treatment will continue at most acid-producing waste sites for a long time, and since metals removal before liming may not be practical, methods may need to be developed to stabilize or fix the treatment products. Lime sludge treatment products are known to retain heavy metal contents as long as excess alkalinity is maintained, but with the moderate solubility of the sludges, metals can be released to the environment.

Lime treatment and sludge stabilization is a high priority area of work defined in the Revised Research Plan. Long-term treatment of acid mine drainage is in essence the main component of the long term liability at many inactive mine sites.

Projected Outputs:

The deliverables will include:

- review of the state-of-the-art, in manual format, of the lime

treatment system for acidic drainage;

- review of chemistry and physical properties of reactions and sludges;
- summary of known methods for stabilizing or "fixing" lime treatment products; and
- recommendations for experimental work on lime treatment and sludge stabilization.

RECOMMENDED **MONITORING**

March 1993

Project 4.6.3: Remote Monitoring Techniques - Review
Budget: $60,000
Sponsor: ..... CANMET
$30,000
Ontario $30,000
Manager: To Be Determined
Contractor: Competitive bidding

Objective:

To identify and evaluate available remote monitoring or sensing techniques and to address the applicability of these techniques for use at acid-generating or potentially acid-generating sites.

Fit With Program:

Closed out and abandoned mines in many cases are inaccessible because of the remoteness of the site or from a deliberate attempt on the part of the owner to reduce liability by restricting public access or complying with regulatory requirements. Because of the cost and difficulty in monitoring closed out sites there is a need to identify and develop cost effective means of monitoring pre-operational, operational and closed out or abandoned sites.

For the purposes of this work, remote monitoring is defined as making measurements from a distance, a distance that can range from satellite to waist height for a hand-held device. The emphasis is being placed on non-intrusive methods of monitoring that do not required excessive disturbance of the site. Technologies such as satellite and aerial sensing of spectral information from vegetation, or the electromagnetic sensing of groundwater resistivity will be included.

Projected Outputs:

A comparison of remote monitoring techniques addressing the applicability to AMD sites will be made. The end point of the project should be to produce a compendium, in handbook form, of remote monitoring technologies for acid mine drainage. Identification of current gaps and recommendations for further development of one (or more) specific technique is also to be considered.

RECOMMENDED **MONITORING**

March 1993

Project 4.8.2: Sediment Sampling Probe Field Application

Budget: $51,000

Sponsor: ..... CANMET $17,038

Falconbridge $12,000

INCO ..... $ 5,000

Ontario $17,037

Manager: C. Weatherell, CANMET

Contractor: AECL

Objectives:

- To conduct a broad reconnaissance for acid mine seepage using the sediment probe at selected sites on the Onaping River and on surface waters near the Kam-Kotia Mine Tailings Rehabilitation Area.
- To measure and quantify groundwater discharge at a minimum of four locations per site where sediment survey results appear interesting or anomalous.
- To evaluate the use of the sediment probe as a method for determining the location of submerged acidified groundwater discharge zones.

Fit With Program:

AECL has developed a method for locating and measuring groundwater discharges which are often obscured by the presence of overlying surface water. A sediment-probe survey employs a boat-towed sediment probe to locate areas where groundwater enters a water body from an underlying aquifer. Groundwaters discharging through bottoms of surface waters are currently detected by measuring sediment electrical conductance. The ability to measure pH, being developed at AECL, is expected to distinguish acidic and non-acidic seepage. When a groundwater discharge zone is located, the survey is complemented by a focused investigation which can quantify and characterize the groundwater flow. A traditional method for locating submerged groundwater discharge zones would require a vast number of piezometers at individual point locations. The proposed technology may allow accurate and inexpensive environmental monitoring to be conducted at specific locations where environmental impact is occurring or is likely to occur.

Projected Output:

An assessment of the success of the Sediment Probe will be made based on the results obtained from each site. Success of the probe for acid mine drainage related monitoring will be measured by its sensitivity, reliability and expected cost.

Project 5.3.2: Expand Databases at Laurentian and University of British Columbia

Budget:	$40,000
Sponsors:	To be determined
Manager:	To be determined
Contractors:	Laurentian University
	University of British Columbia

Objective:

To maintain, update and provide wide access to databases on acidic drainage.

Fit with Program:

Databases have been established at Laurentian University (projet 5.3.1) and University of British Columbia and the information base will continue to expand during the MEND program. During this project, the efforts of the two contractors will be coordinated and a linkage that will avoid duplication of efforts will be established. The databases have to be updated on regular basis and a better promotion is required to meet MENDs objectives.

The Laurentian database is primarily an information base with over 6,000 abstracted references and original documents on acid mine drainage and mine reclamation. Ways to increase use of this data will be determined and put in place in 1993. The proposed database at the University of British Columbia will focus on acid mine drainage data, and data management. Proposed costs are for labour, software, promotion and information distribution.

This project fits precisely with the Priority I component of the Revised Research Plan - Technology Transfer.

Projected Outputs:

A central source of updated information on acid mine drainage will be of benefit for MEND members.

RECOMMENDEDTECHNOLOGY **TRANSFER**
March 1993

Project 5.6.2	Third International Conference on the Abatement of Acidic Drainage
Budget:	$15,000 US
Sponsors:	CANMET, Ontario, Lac Minerals Others to be determined
Manager:	K. Wheeland, Noranda Technology Centre MEND Secretariat

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Objective:

Participate, as a cosponsor with the United States Bureau of Mines, in the Third International Conference on Abatement of Acidic Drainage.

Fit with Program:

To promote communication in the areas of acidic drainage and land reclamation, two major conferences planned for 1994 have been combined into a joint conference which will be held in Pittsburgh in April 1994. The anticipated attendance and number of papers is equivalent to the Second International Conference, hosted by MEND in Montréal, in 1991.

The total attendance is expected to exceed 1000, out of which 600 to 700 people will be concerned with Acidic Drainage. Half of the refereed papers, posters and ½ day sessions will deal with Acid Mine Drainage. MEND participants and contractors are expected to contribute about 35 refereed papers and 10 posters.

As a cosponsor, MEND will participate in planning sessions, reviewing papers, chairing sessions and presenting papers. The contribution will be in the form of promotion material, minor hospitality, or funding. Handling of mailings and publicity in Canada will be coordinated with the Canadian Land Reclamation Association.

Participation in this conference fits precisely with the priorities for Technology Transfer identified in the Revised Research Plan.

Projected Outputs:

This conference is a good opportunity for MEND members to exchange new information with others working in the field of acidic drainage.

RECOMMENDEDTECHNOLOGY **TRANSFER**
March 1993

Project 5.7.1: MEND Newsletter
Budget: $3,000
Sponsors: ..... CANMET
..... $3,000
Manager: K. Mailhiot, CANMET
Contractor: In-House, MEND Secretariat

Objective:

Keep MEND Participants informed of progress on current efforts to find workable and economic solutions to the significant environmental liability posed by Acid Mine Drainage (AMD).

Fit with Program:

To ensure that the objectives of MEND are achieved, results of the research work on acidic drainage have to be transferred to users. Regular publication of a Newsletter is an effective way to inform MEND participants on research progress. It will also deal with the objectives of improving communication among members and promote the existence and purpose of the MEND program.

Information will be given on available technologies, activities of the four main technical committees, MEND publications, people involved in the program, etc. The targeted people are mine managers and operators, although others will benefit from this publication.

Projected Outputs:

The Newsletter, to be published three times yearly, will be distributed widely within Canada and abroad to those interested and involved in solving the problems caused by acid mine drainage.

Project 5.8.1: Economic Evaluation of MEND-developed Technology
Budget: $30,000
Sponsors: ..... CANMET
$30,000
Manager: To be determined
Contractor: To be determined

Objective:

Develop methods for economic evaluation of present technology (AMD prevention, control and treatment) and new technology being developed by MEND.

Fit with Program:

As stated in the Revised Research Plan, the Technology Transfer committee will ensure that useful technology will be available to potential users at reasonable cost. There is a need to develop methods for economic evaluation of new technologies in order to meet the objective. Also, very early rejection of technologies that are uneconomic is needed.

The Technology Transfer committee will prepare a scope of work for preparation of contract.

This project fits precisely with the priorities for Technology Transfer identified in the Revised Research Plan.

Projected Outputs:

A method of economic evaluation will contribute to a better knowledge of the cost of dealing with acidic drainage in Canada.

RECOMMENDEDNEW IDEAS AND INNOVATION
March 1993

Project 6.1	New Ideas Solicitation - Round 1
Budget:	$120 (1993)
Sponsors:	CANMET ($30k), DIAND ($9.2k), HBM&S ($10k), INCO ($10k), Lac($10k), Noranda ($16k), Ontario ($5k), Québec($20k), Teck ($10k)
Facilitator:	K. Wheeland, Noranda Technology Centre
Contractors:	Various

Objectives:

To solicit and develop new ideas and innovation that will provide technology that will significantly reduce the cost of preventing, controlling and treating acid mine drainage.

Fit With Program:

The Revised Research Plan of 1992, approved by the MEND Board in August 1992, requires that about 15% of the remaining expenditures be allocated to soliciting and funding new ideas and innovation. The resulting technology would be:

- inexpensive to implement and maintain and be long-lasting;
- broadly applicable across Canada;
- different from current known methods of preventing and controlling acidic drainage; and/or
- result in very significant reduction in the cost of application of known technology.

In May 1992, a New Ideas Task Force was set up with a mandate to:

- solicit up-front funding from MEND members;
- solicit proposals from proponents, with emphasis on universities (in the first round);
- evaluate proposals and provide seed funding (up to $10,000) for review or development of concepts;
- select project champions and manage contracts; and
- evaluate the results and recommend further action, if any.

Progress to Date and 1993 Program:

Eighty five proposals were received from across Canada, and a total of 12 were accepted for funding. Most of the projects will be complete by mid 1993, and the Task Force will evaluate the results of the projects and recommend to the Management committee which projects, if any, should be supported further by MEND, and incorporated into the programs of the technical committees. A second round of proposal solicitation is proposed for September-October 1993, and this round will focus on proposals from entrepreneurs and research institutions. Proposals from outside Canada will also be considered.

APPENDIX F

MEND Reports Available
Rapports Disponibles sur NEDEM

Prediction/Prévision

1.11.1 Critical Literature review of Acid Drainage from Waste Rock, April 1991. $25

1.16.1a Investigation of Prediction Techniques for Acid Mine Drainage, November 1989. $25

1.16.1b Acid Rock Drainage Prediction Manual, March 1991. $40

1.16.1c New Methods for Determination of Key Mineral Species in Acid Generation Prediction by Acid-Base Accounting, April 1991. $25

1.17.1a Hydrogeochemical Investigation of Reactive Tailings at the Waite Amulet Tailings Site, Noranda, Québec - 1985 Program, July 1986. $25

1.17.1b Hydrogeochemical Investigation of Reactive Tailings at the Waite Amulet Tailings Site, Noranda, Québec, Phase 2 -1986 Program, July 1987. $25

1.17.1c Hydrogeochemical Investigation of Reactive Tailings at the Waite Amulet Tailings Site, Noranda, Québec, Phase 3 -1987 Program, Volume I Report, May 1988. $25

Hydrogeochemical Investigation of Reactive Tailings at the Waite Amulet Tailings Site, Noranda, Québec, Phase 3 -1987 Program, Volume II - Appendices, March 1988. $25

Hydrogeochemical Investigation of Reactive Tailings at the Waite Amulet Tailings Site, Noranda, Québec, Phase 3 -1987 Program, Supplementary Report, March 1989. $25

1.17.1d Hydrogeochemical Investigation of Reactive Tailings at the Waite Amulet Tailings Site, Noranda, Québec, "Generation and Evolution of Acidic Pore Waters at the Waite Amulet Tailings - Final Report", April 1990. $60

1.21.1a Critical Review of the Reactive Acid Tailings Assessment Program (RATAP.BMT2), April 1990. $30

1.21.1b Workshop on Modelling of Reactive Tailings Sponsored by the MEND Prediction Committee, Final Report, August 1990. $40

Prevention & Control/Prévention et Contrôle

2.11.1a Subaqueous Disposal of Reactive Mine Wastes: An Overview, June 1989. $25

A Preliminary Assessment of Subaqueous Tailings Disposal in Benson Lake, British Columbia, March 1990. $25

A Preliminary Assessment of Subaqueous Tailings Disposal in Anderson Lake, Manitoba, March 1990. $25

A preliminary Assessment of Subaqueous Tailings Disposal in Mandy Lake, Manitoba, March 1990. $25

Geochemical Assessment of Subaqueous Tailings Disposal in Buttle Lake, British Columbia, March 1990. $25

2.11.1b Geochemical Assessment of Subaqueous Tailings Disposal in Anderson Lake, Snow Lake Area, Manitoba. $25

Geochemical Assessment of Subaqueous Tailings Disposal in Mandy Lake, Flin Flon Area, Manitoba. $25

2.11.1c A Preliminary Biological and Geological Assessment of Subaqueous Tailings Disposal in Benson Lake, British Columbia, March 1991. $25

Chemical Diagenensis of Submerged Mine Tailings in Benson Lake and Natural Sediments in Keogh Lake, Vancouver Island, British Columbia, 1992. $25

2.11.1d A Critical Review of MEND Studies Conducted to 1991 on Subaqueous Disposal of Tailings, July 1992. $25

2.21.1 Development of Laboratory Methodologies for Evaluating the Effectiveness of Reactive Tailings Covers. March 1992. $40

2.24.1 Manual of Methods Used in the Revegetation of Reactive Sulphide Tailings Basins, November 1989. $20

2.31.1a Heath Steele Waste Rock Study, Phases 1 to 3, March 1992. $40

Treatment/Traitement

3.12.1a Assessment of Existing Natural Wetlands Affected by low pH, Metal Contaminated Seepages (Acid Mine Drainage), May 1990. $25

3.21.1a Study of Metals Recovery/Recycling from Acid Mine Drainage, July 1991. $25

Monitoring/Surveillance

4.1.1 Field Sampling Manual for Reactive Sulphide Tailings, November 1989. $15

4.3.1 RTS-1, RTS-2, RTS-3 and RTS-4: Sulphide Ore Mill Tailings Reference Materials, April 1990. $25

Technology Transfer/Transfert de la Technologie

5.5.1 Reactive Acid Tailings Stabilization (RATS) Research Plan, July 1988. $15

5.6.1 Proceedings - Second International Conference on the Abatement of Acidic Drainage, Montréal, September 16, 17 and 18, 1991. (4 Volumes) $150

5.7.1 1992 Revised Research Plan/Plan de recherche révisé 1992, August 1992. Complimentary

To purchase any of these reports, please contact:

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MEND Reports Available

Rapports Disponible sur NEDEM

Reports Published for the British Columbia Acid Mine Drainage Task Force

1.15.1 Acid Drainage from Mine Walls: The Main Zone Pit at Equity Silver Mines, September 1990. $40

2.23.1 Draft Acid Rock Drainage Technical Guide - Volume 1, August 1989. $56

4.5.2 Field QA/QC Protocols for Monitoring and Predicting Impacts of Acid Rock Drainage, 1992. $30

4.7.1 Monitoring Acid Mine Drainage prepared for B.C. Acid Mine Drainage Task Force, August 1990. $36

4.7.2 Literature Review for Biological Monitoring of Heavy Metals in Aquatic Environments, September 1990. $40

4.7.3a The Effect of Treated Acid Mine Drainage on Stream Macroinvertebrates and Periphytic Algae: An In-Situ Mesocosm Experiment, September 1990. $27

4.7.3b Stream Community Responses to a Gradient of Acid Mine Drainage Additions, 1992. $30

4.7.4 Review of Sediment Monitoring Techniques prepared for B.C. Acid Mine Drainage Task Force, November 1990. $36

4.7.5 Evaluation of "B.C. Mine" for Application to Acid Mine Drainage Regulations, 1992. $50

4.7.6 Use of Paleolimnological Techniques to Assess the Effects of Acid Rock Drainage in British Columbia, 1992. $30

Other Reports Available from the British Columbia Acid Mine Drainage Task Force

Acid Mine Drainage - Designing for Closure, May 1990. $111

Hydrogeological Assessment and Development of AMD Control Technology for Myra Falls Waste Rock, September 1990. $40

Investigation & Design of Mine Dumps Interim Guidelines, May 1991. $69

Kutcho Creek Project Acid Generation Testwork Phase II, September 1990. $40

Literature Review on In-Situ Treatment of Acidic Rock Dumps with Lime or Lime/Phosphate, 1992. $20

Operation & Monitoring of Mine Dumps Interim Report, May 1991. $69

Shotcrete Application of Cementitious Sealant Materials for Acid Rock Drainage Control Prepared for B.C. Acid Mine Drainage Task Force, April 1991. $36

Survey of Closed and Abandoned Mines in B.C. for Acid Mine Drainage, 1992. $50

Use of Zeolite to Treat Acid Rock Drainage from Britannia Mine, 1992. $20

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